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Due: 2:00 p.m.
Friday, December 7, 2018

PREPARED EXCLUSIVELY FOR:

Association of Central Oklahoma Governments (ACOG)

Request for Proposals #2019-01: The Central Oklahoma Alliance of Government Agencies 2019 (COAGA 2019), Regional Digital Orthophoto Images and Associated Data

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sanborn

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December 5, 2018

Mr. John Sharp
ACOG
4205 N. Lincoln Blvd.
Oklahoma City, OK 73105

Re: Request for Proposals #2019-01: The Central Oklahoma Alliance of Government Agencies 2019 (COAGA 2019), Regional Digital Orthophoto Images and Associated Data

Dear Mr. Sharp:

On behalf of The Sanborn Map Company, Inc. (Sanborn), it is my pleasure to submit our qualifications to you for the project referenced above. We applaud COAGA 2019 for the robust GIS that your participants have developed and continue to maintain. High quality, accurate, geospatial data is critical in continuing to support all your users and applications and Sanborn is excited about the opportunity to support the participants this year in enhancing their GIS.

Sanborn, a quality-focused company with a robust Quality Management System (QMS), was established in 1866. Headquartered in Colorado Springs, Colorado, it is the country's oldest map company and one of the largest lidar, photogrammetric mapping and GIS data conversion firms in the United States. With more than 100 personnel dedicated solely to mapping and GIS activities, Sanborn has unparalleled depth and technical expertise available to its clients. We have been providing modern mapping services since the 1960's, pioneered digital orthoimagery production in 1989, purchased our first lidar sensor in 1999, and have provided planimetric mapping services similar in scope to the COAGA 2019 project for hundreds of other cities, counties, regional entities and states.

Sanborn has built a strong project team that offers exceptional levels of experience and expertise for each project component and is committed to the COAGA 2019 program. We have assigned Ms. Bridget Marcotte, PMP, as Project Manager and single point of contact. Ms. Marcotte managed the previous COAGA 2015 project, as well as the City of Edmond, OK, programs in 2016 and 2018. She is thoroughly familiar with the requirements and specifications of your program. Many of the same personnel that worked on the previous COAGA 2015 and Edmond projects will again support Ms. Marcotte for the individual tasks. This team's experience brings great value with our familiarity with the specifications, and the ability to hit the ground running with an expedited startup phase, which sets the stage for schedule and budget adherence.

We can perform all facets of your project and comply with all specifications. If you have any questions or need clarification of any part of our proposal, please contact Ms. Krysia Sapeta, Director, Strategic Accounts, at ksapeta@sanborn.com or (321) 298-1744. We are excited about the project and hope we have the opportunity to introduce you to the key members of our team.

Sanborn acknowledges receipt of the email dated November 29, 2018, containing the AOI shapefiles and the Affidavit of Non-Collusion form, as well as the email dated November 30, 2018, containing a link to the Planimetric Data zip file.

Sincerely,

John R. Copple
President/CEO

Enclosures

Table of Contents

Section 1 – Project Overview

The Sanborn Map Company, Inc. (Sanborn), is pleased to present this proposal to the Association of Central Oklahoma Governments (ACOG) in response to the Request for Proposals (RFP) #2019-01: The Central Oklahoma Alliance of Government Agencies (COAGA) 2019, for Regional Digital Orthophoto Images and Associated Data.

Company Overview

Sanborn is a full-service geospatial company that has been in continuous operation since 1866. Sanborn offers comprehensive geographic information solutions to city, county, regional, state, and federal government agencies, private companies, and international clients. Our services include:

- GPS ground control surveys
- Aerial imagery acquisition, including airborne GPS and IMU controlled imagery, using advanced digital aerial imagery sensors
- Digital orthophoto imagery creation
- Digital oblique imagery creation and oblique imagery viewing platform
- Airborne, terrestrial and mobile lidar data acquisition and production for digital elevation/terrain and feature modeling
- Planimetric and topographic mapping
- Remote sensing analysis, including change detection, land cover/land use mapping, impervious/pervious surface mapping, and fire risk assessments
- Data collection, and utility and asset inventory creation
- 3D infrastructure modeling and simulation
- Parcel, facility and data conversion mapping
- GIS and CAD database creation
- GeoIT support including data analysis, data hosting, website creation, and custom application development
- Unmanned aerial systems (UAS)
- Indoor mapping

Sanborn is headquartered in Colorado Springs, Colorado. With four technology centers across the United States, Sanborn offers local presence, extensive resources, and quick response times.

Our team of nearly 125 mapping and GIS professionals has decades of experience in all facets of the industry, proven project management skills, and expertise in many database systems and GIS platforms. As a quality-focused company, Sanborn is dedicated to excellence and to fulfilling our clients' needs in an efficient, accurate, and timely fashion.

The Sanborn Map Company, Inc.	
Address	1935 Jamboree Dr., Suite 100 Colorado Springs, CO 80920
Telephone/Fax	(719) 593-0093 / (719) 528-5093
Internet Address	www.sanborn.com
Year Established	1866
Office to Provide Services	Colorado Springs, Colorado (Corporate Office)
Other Offices	▪ Pelham, NY ▪ Charlotte, NC ▪ Merritt Island, FL
Type of Ownership	The Sanborn Map Company, Inc. is a privately owned company incorporated in the State of Delaware, U.S.A.
Registration	Sanborn is licensed to do business in the State of Oklahoma, under ID number 2312026563

History

Sanborn is a successful, well-established mapping company in the United States. In 1866, our focus was the creation and maintenance of fire insurance maps used primarily for fire insurance underwriting. Sanborn has never lost focus of our original function as a map-maker, and today Sanborn utilizes the latest equipment and technology, while continually developing improved processes, to produce and deliver quality geospatial solutions for our contemporary clients.

Sanborn Chronological Experience of Service Offerings	
Service	**Offered Since**
Ground Surveys	1866
Aerial Photography	1966
Photogrammetric Mapping	1966
Digital Photogrammetric Mapping	1979
Digital Terrain Modeling	1984
Digital Orthophotography	1988
Lidar	1998
Digital Vertical Aerial Imagery	2004
Digital Oblique Aerial Imagery	2011
UAS Operations	2013

- In 1960, Sanborn expanded into new markets with a variety of new thematic map styles such as market radius, noise abatement, and land use maps. Sanborn also continued to develop services using computers for tax parcel mapping and land/building usage databases.
- Sanborn began offering aerial photography and mapping services in 1966 as the result of a merger with an aerial mapping firm.
- In 1984, Sanborn became one of the first companies to use digital terrain modeling and contour interpolation techniques to produce topographic data.
- In 1988, Sanborn was the first company to develop and implement a commercially viable system for the production of digital orthophoto imagery.
- Sanborn continued to expand its services by purchasing its first lidar system in 1998; and, invested in its first terrestrial lidar scanning instrument in 2003, to complement the aerial lidar business line
- In 2004, Sanborn acquired its first digital aerial cameras, and has since continued to invest in the most useful and effective equipment
- Sanborn acquired its first digital oblique aerial imagery sensor in 2011, and now owns 5 Track'Air MIDAS systems.

- In 2013, Sanborn acquired three new Vexcel UltraCam Eagle cameras, and implemented them into the aerial photo production business line.
- In 2014, Sanborn acquired the latest aerial lidar sensor technology with the procurement of a Leica ALS70-HP lidar system, and now has 2 of these systems.
- In 2015, Sanborn acquired a Leica RCD30 medium format mapping camera to enable simultaneous lidar and 4-band imagery collection.

Since acquisition of our first lidar and digital imagery aerial systems, Sanborn has collected data for and mapped hundreds of thousands of square miles of terrain, and is one of the most advanced lidar and digital imaging firms today.

Sanborn owns and operates four lidar instruments and thirteen digital Imaging sensors, and operates a fleet of aircraft consisting of two turbine aircraft, three twin engine piston aircraft, three single engine aircraft, and three unmanned aerial systems (UAS).

Sanborn continues to set industry standards in excellence. The Sanborn name is synonymous with high quality mapping and GIS services. Our team of mapping and GIS professionals has decades of experience in all facets of the industry, proven project management skills, and expertise with many data collection and processing technologies, database systems and GIS platforms. In all aspects, Sanborn provides innovative solutions and quality service to our customers.

Subcontractor Overview

To increase Sanborn's capacity and resource base, Sanborn has partnered with Shandong Eastdawn Corporation, a subcontracting partner with Sanborn for over 10 years to provide production support. Eastdawn is one of our most trusted subcontractors, and they performed a similar production support role for both the COAGA 2015 project, and the City of Edmond mapping services projects in 2016 and 2018. Mr. Steven Wood, PLS, a long-time independent consultant partner, is providing survey and ground control support. He, too, provided similar support on the City of Edmond projects.

Subcontractor Management

For any project that utilizes subcontracted services and products, it is essential to have an experienced subcontract manager, subcontractor SOW, and a subcontract management plan. Sanborn's quality processes make certain these documents and personnel are in place is to ensure purchase orders are properly executed, providing the appropriate controls to meet the program schedule, budgets, and technically compliant services and products, and to review the progress of the subcontractor and subcontract management activities.

Shandong Eastdawn Corporation

Established in November 2001, Shandong Eastdawn Corporation (Eastdawn) is a global geospatial data production and remote sensing company providing comprehensive spatial information solutions for both commercial and government customers. Eastdawn is a subsidiary of Beijing Eastdawn Information Technology Co. Ltd., headquartered in Beijing, and is one of the largest privately owned geospatial data production companies in China.

Eastdawn is a leading international geospatial service provider with established clients in Asia, Europe, South America, Africa and North America. As a Class-A surveying and mapping company certified by the National Administration of Surveying, Mapping and Geoinformation, the company serves its customers across a wide range of geospatial services including GIS, lidar and photogrammetry from space, airborne and terrestrial data sources. Based in Jinan, Shandong Province, Eastdawn has sales offices in China, Japan, Europe and the USA. The company is highly customer focused, providing superior levels of service for its clients.

Eastdawn offers high-quality, customized data processing services through their specific large-scale intellectual information processing system. In the data application sector, Eastdawn possesses a solid technical background and a broad range of project implementation experience, such as multi-source data processing, mass spatial data management, and geographical 3D visualization and analysis. Eastdawn obtained a Class-A Surveying and Mapping Certificate from the State Bureau of Surveying and Mapping (SBSM) in 2008.

Mr. Steve Wood, OK PLS

Mr. Steve Wood, PLS, CP, will complete and certify the ground control survey phase. Mr. Wood is a certified State of Oklahoma Professional Land Surveyor #1116 and has been registered since July 11, 1980. Mr. Wood combines an extensive land surveying and civil engineering background with more than 42 years of project management experience in engineering, land development, surveying and photogrammetry. His surveying experience is comprehensive and includes many years of practical field assignments and office management of more than a dozen survey field crews. Projects include almost every type of surveying including land boundary, construction staking, flood insurance cross section surveys, ALTA minimum standard surveys, power plant layout, right of way takings, GPS control surveys for control densification and photo control projects, precise second order control surveys, differential and on the fly GPS field inventory of utilities, and Department of Defense GIS mapping and field inventory. Mr. Wood has also served as the Surveyor in Responsible Charge overseeing multi-participant municipal mapping and surveying projects for many countywide landbase mapping projects throughout the US and overseas. Mr. Wood has helped implement innovative surveying uses of current technology to accomplish timely and economical survey solutions throughout his career.

Project Approach Summary

Sanborn has the capability and capacity to perform all services identified in the RFP.

Sanborn owns the required aircraft, and aerial sensors required for the critical acquisition phase of the program, which is the foundation for quality data and provides the ability to maintain schedule. We are committed to the acquisition of digital aerial imagery during the spring of 2019 under ideal conditions for imagery capture in the project area, as well as acquisition of lidar during the same timeframe.

Sanborn possesses experienced and certified staff, state-of-the-art equipment, relevant similar project experience, and strong resolve to meet or exceed your requirements and accuracy specifications. Our goal is to provide COAGA 2019 members high quality, accurate, crisp, interpretable, as well as aesthetically pleasing orthophotography. If selected by the participants, newly acquired high accurate lidar will be hydro-flattened and quality derivative products generated included the interpolation of contours. We have also provided the option for a 100% comprehensive update of planimetric features.

Scope of Work

Sanborn understands that COAGA 2019 wishes to procure:

- New color aerial imagery.
- Establishment or recovery of ground control as needed to support the project managed by a certified Oklahoma PLS
- Aerial triangulation services as needed to position, orient, and tie the newly-acquired aerial imagery, and verify the integrity of the control solution;
- An updated or new Digital Elevation Model (DEM) that will support accurate orthorectification;
- All members require new 3-inch, 6-inch or 12-inch spatial resolution, 3-band, 8-bit-per-channel, RGB true natural color digital orthophotography. **Please note** that Sanborn offers delivery of the 4th band (NIR) as an optional product, at no additional costs. Individual members may choose to have their product delivery at either 3-band or 4-band delivery.
- Sanborn will ensure that sufficient ground control will be surveyed to ensure that the new orthophotography will meet or exceed ASPRS Class 1 specifications and the DEM will be updated as necessary to properly rectify the entire project area, including areas of change. The new imagery acquired and supported with additional ground control will provide enhanced accuracy.
- Delivery of orthophotography in uncompressed GeoTiff PLSS tile format and associated TIFF World header files, for the relevant resolutions
- Additional copy of all tiles re-sampled to 1-foot resolution in uncompressed TIFF format files with associated TIFF World header files
- MrSid and Lossless JP2000 compressed files of the entire COAGA 2019 project Area
- Supplemental documentation, reports, and deliverables created as a part of the production process for all data layers, as outlined in the RFP, including FGDC compliant metadata.
- Optional Products
  - Optional MrSID Mosaic and JP2000 products, as defined for each entity
  - Updated planimetric data layers for Edmond, and Norman; all newly acquired planimetric data will meet or exceed ASPRS Class 1 specification; the existing data will meet the original compiled specification.
  - Optional hydro-flattened lidar for Edmond (with updated HE-DEM and 1-foot contours) and Norman (with updated HE-DEM and 1-foot or 2-foot contours). All lidar and lidar products will meet or exceed ASPRS Class 1 specifications.

Mapping limit AOI's are understood to be as outlined in Appendices C through I of the RFP and additional details for each entity. The total area of the base project is approximately 1,351.85 square miles. The data layers are to be geo-referenced and projected in the:

- NAD83 (HARN) Oklahoma State Plane, South Zone 3502 NAVD88 US Survey Feet – Moore and Norman
- NAD 1983 Oklahoma State Plane, North Zone 3501 NAVD88 US Survey Feet – Edmond, Del City, Midwest City and Canadian County

Technical Overview: Key Production Tasks

Sanborn provides a solution for all the project requirements, with no omissions:

Project Management/Schedule: Sanborn has an established Project Management Office (PMO) and our management approach encompasses best practices of the Project Management Institute (PMI). A key element for project control of budget and schedule is the installation of the project schedule in our Earned Value Management (EVM) system. This management/production tool tracks all project resources throughout the project life-cycle and ensures adherence to schedule. Ms. Bridget Marcotte, PMP, is assigned as Project Manager and single point of contact. She is familiar with the requirements of the program, and has previously worked with both COAGA 2015 and the City of Edmund in 2016 and 2018.

Resources/Capacity: Timely, consistent, and quality collection of aerial imagery and lidar data is the cornerstone for generating accurate, quality data. Sanborn owns eight (8) aircraft, (13) Digital Cameras and two (2) aerial lidar systems. This Capacity along with our robust hardware and software equipment sets the stage for adherence to schedule.

Imagery Camera System: Collection of ABGPS/IMU-controlled vertical color imagery for this project will be performed by Sanborn with the advanced UltraCam Eagle digital aerial camera system with 3rd generation architecture. Sanborn owns three (3) Microsoft Eagle sensors that our proposed for your program. We have used the Eagle on numerous mapping programs requiring similar mapping standards, including the COAGA 2015 and City of Edmund projects in both 2016 and 2018. The Eagle acquires multispectral imagery (R, G, B, NIR) and features state-of-the art CCD technology, a lower signal-to-noise ratio and better interpretability in areas where shadows are unavoidably present and the 100mm lens minimizes building displacement/lean.

Aerial Imagery Acquisition: One of the most critical phases of this project is acquisition of the color 2019 aerial imagery, and is the cornerstone for meeting schedule and generating highly accurate and quality photogrammetric basemap products. We have sufficient resources to provide COAGA 2019 the assurance that the acquisition is completed on time and within the environmental parameters, for the critical acquisition phase. Aerial acquisition status is updated **daily**, and will be provided to COAGA 2019 via a password protected website and illustrated with flight line design plans and phases of completion. Imagery will be acquired at 6-inch resolution for Cities of Moore and Norman, and 12-inch for Canadian County. Imagery will be acquired at 3-inch resolution for Edmond, Del City and Midwest City. There will be no re-sampling of the data; the initial pixel resolution will be of finer resolution than the final product. The imagery will be acquired to result in complete coverage of the designated flight areas with a minimum of a 200-foot buffer outside of the designated flight areas. Where the City limits are in a portion of a PLSS section, the deliverables shall include the complete section. Sanborn will provide COAGA 2019 with early access to the georeferenced imagery ***within 14 days of being flown***, via a URL. This imagery can be viewed in ArcGIS Desktop or other GIS programs which support OGC web map services.

Ground Control & Aerial Triangulation: Sanborn will utilize existing ground control on this project to the fullest extent possible, and augment it with new, photo-identifiable ground control points where needed. Mr. Steve Wood, Oklahoma PLS #1166, will perform and certify the survey. Using the ground control survey information, camera calibration information and Airborne GPS/Inertial Measurement Unit (AGPS/IMU) data acquired during the aerial flight, a Fully Analytical Aerial Triangulation (FAAT) solution will be completed, to establish the orthophotography and derivative product accuracies.

Accuracy: Sanborn has successfully completed hundreds of mapping programs similar in size and scope to the COAGA 2019 program. We have designed the project to meet or exceed the required ASPRS Class 1 mapping standards. All work with be reviewed, accepted and documented by our Chief Photogrammetrist, Mr. Doug Zehr.

Digital Color Orthophotography: As early as 1988 when Sanborn pioneered Digital Orthophoto production, we have had a department of experienced imaging technicians dedicated solely to the creation of orthophotography. Our software and workflow will ensure geometrically accurate and radiometrically pleasing imagery, and will facilitate elimination of defects such as image smearing, bridge distortions, radial distortion, seamline /mosaicking errors, and unsightly image artifacts. The DEM source will be either a new lidar dataset or an updated existing DEM. Interim deliverables and pilot/sample data will be provided to COAGA 2019, and COAGA 2019 members will be involved in key decisions regarding subjective aspects of image radiometry.

No-Cost Option for the 4th NIR band: Our software enables Sanborn to orthorectify all four bands simultaneously, so there is no upcharge over collection and processing of 3-band imagery to deliver a 4-band orthorectified imagery product, providing added value to COAGA 2019. The 4-band data is invaluable for analyzing environmental conditions.

Web-Based Client QC (GeoServe): For the orthophotography review, Sanborn will provide an optional, no-cost web-based quality control application for COAGA 2019, to allow multiple users to review the orthophotography and provide comments instantly back to Sanborn. Data is served from a central data server at Sanborn to the customer-side computer and uses a mapping interface from within a standard web browser, for COAGA 2019 to review the orthophotography. The tool accelerates the review process and expedites final product acceptance and delivery.

Metadata and Reports: Sanborn develops FGDC-compliant metadata for a majority of our clients and will provide detailed reports/metadata for each deliverable product, as well as supporting documentation and reports.

Lidar (Option): Sanborn purchased our first lidar sensor in 1999 and since then we have acquired and mapped over 500,000 (½ Million) square miles of elevation data. Sanborn currently owns and operates two (2) state-of-the-art Leica ALS70-HP aerial lidar systems and proposes to use this system for COAGA 2019's project. For specified areas of interest, **Sanborn** will acquire and produce hydro-flattened lidar products for the entire area, and the data will meet or exceed ASPRS Class 1 accuracy Standards. The lidar will conform to both ASPRS Positional Accuracy Standards for Digital Geospatial Data and USGS lidar specifications.

Topography (Option): The newly acquired lidar data will be used to support the production of new contours for Edmond and Norman. This lidar data will be sufficiently enhanced with 3-D breaklines to support accurate contour interpolation, and the contours will meet or exceed ASPRS Class 1 specifications for the relative contour interval and scale.

Planimetric Update (Option): For specified areas of interest, experienced Sanborn technicians will perform a comprehensive update of the entire area in a 3D stereo-compilation environment, by manual technician review. All newly digitized linework will meet exceed ASPRS Class 1 accuracy specifications; existing linework will maintain the original specification it was compiled at and will be edge-matched, share common boundaries between features, and be topologically structured. Sanborn has both automated and manual control methods in place to ensure high quality vector data.

IT infrastructure: All of COAGA 2019's data will be maintained on Sanborn's robust, state-of-the-art IT infrastructure, capable of processing, storing, and communicating large volumes of data reliably and securely. Sanborn's production IT infrastructure is made up of a powerful 300 node computer farm and more than 4 petabytes of raw storage. The Tier 1 storage is capable of sustaining a data through-put of 4000 Mb/s while the Tier 2 storage sustains throughputs of 1000 Mb/s. To put this in perspective, most mapping firms acquire and process 35,000 exposures annually; in contrast Sanborn acquires five times this amount of imagery every year, and processes ten times this amount on an annual basis.

Quality Control/Quality Assurance: Quality control validation points are inserted into the overall program process at key points and quality assurance protocols are completed prior to submission of deliverable products. Data consistency and quality is of critical concern for every project. This is accomplished through rigorous quality testing of the interim dataset at all phases of the production process, and closed loop feedback communications with production staff to ensure our staff meet customer expectations and understand COAGA 2019's specifications. Sanborn places an emphasis on problem prevention rather than dependence on detection after occurrence. Sanborn places an emphasis on problem prevention rather than dependence on detection after occurrence. Sanborn management will exercise tight control over the project, and coordinate our efforts with those of COAGA 2019's management and staff to ensure that this project is completed on time, to specification, and within budget.

Experience

Proven Track Record with Similar Projects: Sanborn has completed programs that range from small cities and counties, to multi-year statewide and national Geospatial programs. Sanborn implemented the first commercially successful digital orthophotography production program in the industry in 1988 and since that time, Sanborn has mapped over 3 Million square miles of imagery. We began lidar acquisition and processing in 1999, and have been performing planimetric feature extraction since the 1970's. We are very familiar with the project requirements and specifications, having performed mapping services for COAGA 2015, as well as mapping the City of Edmund in 2016 and 2018.

Personnel: Our experienced and certified staff includes Certified Photogrammetrists, lidar experts, registered land surveyors, survey technicians, pilots, aerial photographers, cartographers, photo interpreters, stereo-compilers, CAD technicians, image processing specialists, computer programmers, and GIS design professionals. Their vast experience and close attention to detail ensures that the most effective mapping solutions are developed in a cost-effective manner.

Our goal in responding to the RFP is to provide convincing evidence that there is no risk to the Sanborn approach, and that COAGA 2019 will benefit from selection of the Sanborn team.

Valuable No-Cost Options

Sanborn provides several differentiators in our proposal, which are advantageous to COAGA 2019:

- **QuickView Imagery Web Service:** Sanborn is offering to provide early access to georeferenced imagery Sanborn's QuickView service, which provides our clients with the ability to see captured imagery within 14 days of being flown. This service is presented as a web-based application, a mapping interface from within a standard web browser, or an URL that can be used in ArcGIS Desktop or other free open source software for GIS that consume OGC web map services. Access to the imagery allows users to begin interacting with the imagery in a timely manner and represents a quick look at recently captured images.
- **4-Band (Red, Green, Blue, Near-Infrared) Delivery:** Sanborn provides delivery of the 4th Near-Infrared band at no additional cost. This band is valuable for environmental remote sensing applications.
- **GeoServe:** Sanborn's web-based quality control applications are provided for use by COAGA 2019. Data is served from a central data server at Sanborn to the COAGA 2019-side computer and uses a mapping interface from within a standard web browser, for COAGA 2019 to review the data. GeoServe is provided for all primary deliverables. Sanborn's GeoServe Online QC tool accelerates the review process and expedites final product acceptance and delivery.

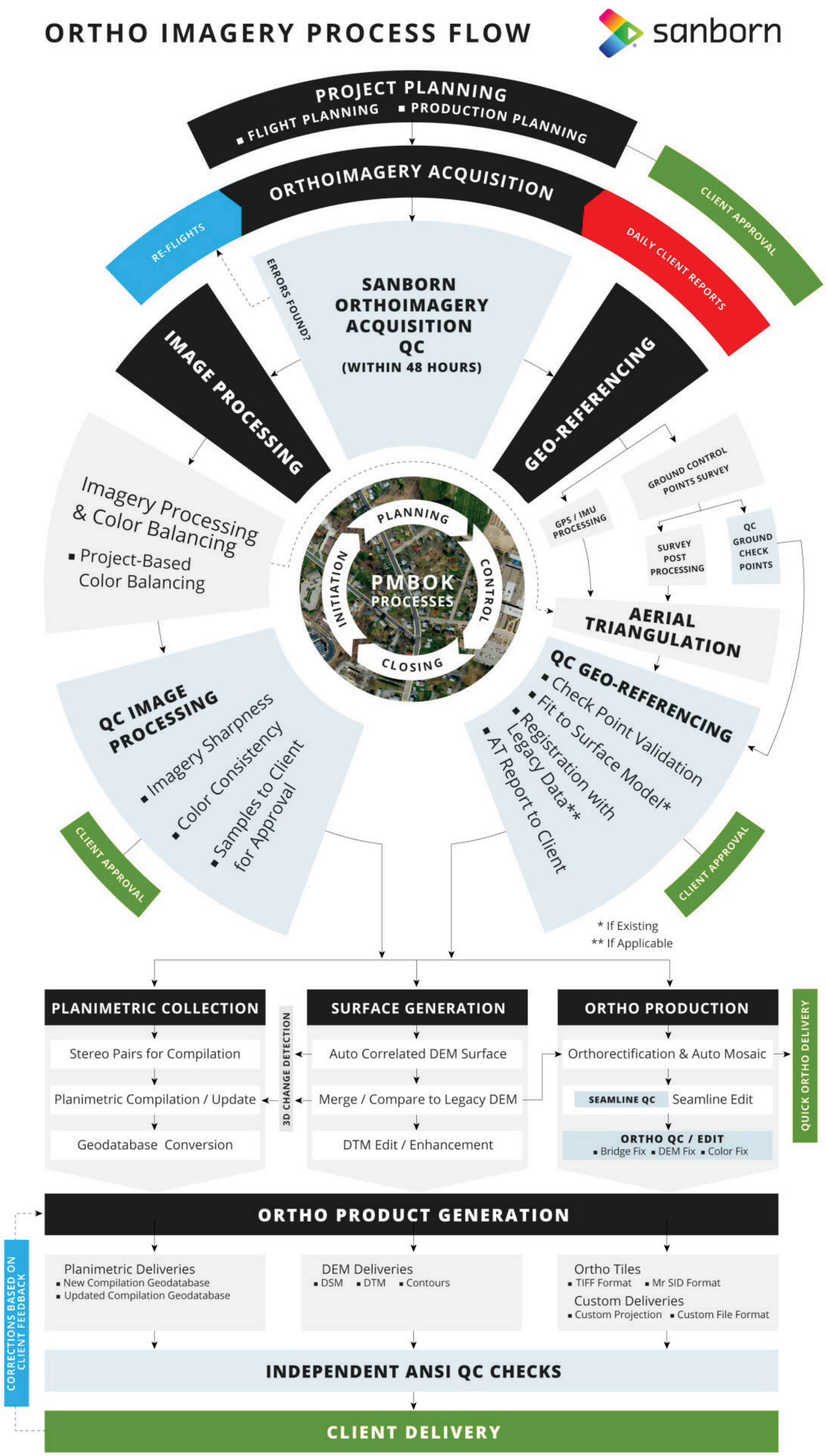
Section 2 – Project Approach

Introduction

This section provides a detailed description of the equipment, methods, and procedures Sanborn will use to collect new digital aerial imagery, and produce the required derivative data products and supporting materials in full conformance with the standards and specifications outlined in the RFP. This includes project management, and the steps taken to provide quality assurance and control throughout the entire process.

Project Understanding and Background

Sanborn will perform or provide for all of the necessary tasks, including but not limited to primary data acquisition (ground control surveying, lidar and aerial imagery), aerial triangulation, digital elevation modeling, orthorectification, planimetric data update, contour production, quality assurance and control, project management and administration, and generation of full documentation and metadata for the project. All deliverable data products will be in full compliance with the standards and specifications set forth in the RFP.


ORTHO IMAGERY PROCESS FLOW
sanborn
PROJECT PLANNING
FLIGHT PLANNING
PRODUCTION PLANNING
ORTHOIMAGERY ACQUISITION
RE-FLIGHTS
DAILY CLIENT REPORTS
CLIENT APPROVAL
ERRORS FOUND?
SANBORN ORTHOIMAGERY ACQUISITION QC (WITHIN 48 HOURS)
IMAGE PROCESSING
GEO-REFERENCING
Imagery Processing & Color Balancing
Project-Based Color Balancing
GPS / IMU PROCESSING
GROUND CONTROL POINTS SURVEY
SURVEY POST PROCESSING
QC GROUND CHECK POINTS
PLANNING
INITIATION
CONTROL
CLOSING
PMBOK PROCESSES
AERIAL TRIANGULATION
QC GEO-REFERENCING
Check Point Validation
Fit to Surface Model*
Registration with Legacy Data**
AT Report to Client
QC IMAGE PROCESSING
Imagery Sharpness
Color Consistency
Samples to Client for Approval
CLIENT APPROVAL
CLIENT APPROVAL
* If Existing
** If Applicable
PLANIMETRIC COLLECTION
Stereo Pairs for Compilation
Planimetric Compilation / Update
Geodatabase Conversion
3D CHANGE DETECTION
SURFACE GENERATION
Auto Correlated DEM Surface
Merge / Compare to Legacy DEM
DTM Edit / Enhancement
ORTHO PRODUCTION
Orthorectification & Auto Mosaic
SEAMLINE QC
Seamline Edit
ORTHO QC / EDIT
Bridge Fix
DEM Fix
Color Fix
QUICK ORTHO DELIVERY
ORTHO PRODUCT GENERATION
CORRECTIONS BASED ON CLIENT FEEDBACK
Planimetric Deliveries
New Compilation Geodatabase
Updated Compilation Geodatabase
DEM Deliveries
DSM
DTM
Contours
Ortho Tiles
TIFF Format
Mr SID Format
Custom Deliveries
Custom Projection
Custom File Format
INDEPENDENT ANSI QC CHECKS
CLIENT DELIVERY

Proposed Sensor Technology

Sanborn has fully implemented digital aerial camera technology and adapted our workflows to maximize the benefits of these systems. Sanborn was one of the first companies in the United States to purchase and operate large-format, metric digital aerial cameras, and over the intervening years, has developed extensive expertise in the implementation and use of digital camera technology. We have worked closely with manufacturers to ensure that our workflow, from acquisition through image processing, supports our subsequent production processes, and Sanborn has been integral in the manufacturer's development of improvements to their technology. Sanborn has been working with Vexcel Systems since 2004, following our initial acquisition of their UltraCam D camera system. In total, Sanborn has used digital aerial cameras for over 3,000,000 square miles of imagery collection and processing for clients across the United States. A description of the sensor system, as well as quality assurance measures taken to ensure its readiness for use on a project is outlined below.

The Vexcel UltraCam Eagle Digital Aerial Imagery Sensor

Sanborn procured the third-generation Vexcel UltraCam Eagle digital aerial imagery sensor, which it proposes for this project, in February, 2013. The features and benefits of this system include:

- State-of-the-art CCD technology, 14-bit dynamic range, and a lower signal to noise ratio, resulting in nearly twice the brightness values of the sensors previously used for imagery collection by Sanborn, and providing exceptionally sharp, high-quality imagery even in less-than-ideal weather/atmospheric conditions, and better interpretability in areas where shadows are unavoidably present.
- A 5.2 µm pixel size at the sensor, compared to 12 µm for the Intergraph DMC sensor it has replaced. This allows Sanborn to collect imagery at much higher altitudes than was previously possible, while still meeting the accuracy and resolution requirements set for a project.
- The higher imagery collection altitudes made possible by the UltraCam Eagle minimize air traffic control/airspace incursion issues, and result in a much larger exposure footprint (approximately 2.5 times that of the DMC) on the ground. This translates to a smaller number of exposures needed to cover a project area, faster collection times, less ground control, and lower cost to the client.
- Utilizes the best optics module currently available on the market. Additionally, the 100mm lens system provides a broader "central perspective", resulting in less radial displacement (e.g. "building lean") in the image data.
- Based upon proven, stable, frame sensor technology that results in maximum operational reliability and the most precise image geometry. In contrast to "push-broom" or line sensors that are completely reliant on the AGPS/IMU technology to generate usable data, normal photogrammetric solutions can be applied to the UltraCam Eagle's imagery, enabling normal use of that imagery in the event of problems with the AGPS/IMU sub-systems. While Sanborn operates the best GPS/IMU systems available and failure is unlikely, this mitigates operational risk to Sanborn and the COAGA 2019.

- Forward Motion Compensation (FMC) implemented through TDI (Time Delayed Integration) technology.
- Solid state, in-flight exchangeable data storage modules result in higher reliability and longer mission times.
- Suitable for a wide range of applications, from large-scale engineering mapping to low-resolution remote sensing projects.
- Outputs image data in industry-standard file formats can be ingested into and processed with any standard softcopy photogrammetric system on the market
- Can be operated within a wide range of flying heights, and is operationally suitable for operation in both pressurized and unpressurized aircraft.
- Utilizes a modular hardware design, which enables easy replacement or upgrade of components. This includes field replacement of the lens system, enabling utilization of different focal length lenses.
- Extremely rugged camera frame and peripheral hardware design, leading to maximum operational reliability. Constructed of high-grade industry components for safe and reliable aircraft installation (high grade connectors, environment tests against DO160, a minimum of cable connections, crash load tests against DO160) and operation.

The gyro-stabilized camera mounts in Sanborn's aircraft were upgraded to the latest Track'Air systems at the same time as the UltraCam Eagle sensors were acquired, and represent the most advanced technology currently available on the market, ensuring a stable camera platform and high-quality imagery even in the event of unexpected, turbulent flight conditions.

Technical Specifications for Sensor

Technical specifications for the UltraCam Eagle are as follows:

Vexcel UltraCam Eagle Specifications	
High-resolution 20K x 13K Panchromatic camera:	Final output image is 20,010 x 13,080 pixels
Field of view:	54.7° cross track x 37.4° along track
Panchromatic camera lens system:	f = 100.5mm with 1/5.6 lens aperture. Shutter speed options 1/500 to 1/32 sec
Multispectral 6.7K x 4.4K cameras (x4):	red, green, blue, and near infrared each 6,670 x 4,360 pixels
Pan Sharpening Ratio	3:1
Multispectral camera lens system:	f = 100.5 mm with 1/4 lens aperture. Shutter speed options 1/500 to 1/32 sec
Physical pixel size pan:	5.2 µm
Physical pixel size multi-spectral:	15.6 µm
Input data quantity per image:	842 megabytes, 260 megapixels
Maximum frame rate:	>1.8 seconds per frame
CCD signal to noise ratio:	72 dB
Radiometric resolution in each channel	12 bits; workflow dynamic:16 bits
In-flight data storage system:	Solid state disc pack, Capacity ~3.3 TB, ~ 3,800 images per swappable unit
Time needed to swap disc pack inflight:	Less than 2 minutes
Data recording time @ 10 cm GSD, 60% forward overlap, 140 kts:	8 hours per disc pack

Radiometric and Geometric Calibration

In order to facilitate collection of imagery with the best possible radiometric and geometric properties, Sanborn ensures the completion and currency of two independent camera calibration/verification processes. The first laboratory calibration is performed by the manufacturer. The second is Sanborn's internal camera calibration/verification procedure. Sanborn will provide current manufacturer calibration certificates for all sensors used on the project, as well as a report based upon Sanborn's own methods and procedures to verify the accuracy of any sensors used on the project. For example, each time a camera is installed in an aircraft, a complete geometric calibration is performed in order to ensure the accuracy of the platform. This process is referred to as a "boresight."

Manufacturer Calibration

Prior to delivering a digital sensor to Sanborn, the manufacturer performs the following calibration procedures.

- **Geometric calibration:** The geometric calibration is based upon a set of 84 images of a defined geometry target with 240 control points. The number of point measurements is over 60,000. This calibration procedure guarantees that the remaining lens distortions are less than 0.002 mm.
- **Verification of lens quality and sensor adjustment:** The targets used for the geometric calibration also hold resolution targets, which are used to derive the modulation transfer function (MTF) across the field of view of camera. The MTF is derived for the meridonial (tangential) and sagital (radial) component of signals at frequencies of 10, 20, and 40 line pairs per millimeter for various aperture settings. The MTF is guaranteed to be less than -7dB in the field of view that typically is used for mapping applications, even for the 40 line pairs per millimeter resolution.
- **Radiometric calibration:** The radiometric calibration is based on a series of 60 flat field images for each aperture size and sensor. The flat field is illuminated by two normal light lamps with known spectral illumination curves. These images are used to calculate the specific sensitivity of each pixel to compensate local as well as global variations in sensitivity. Sensitivity tables are calculated for each sensor and aperture setting, and applied during post processing from level 0 to level 1. The resulting image has virtually no vignetting caused by the camera system.
- **Calibration of defective pixel elements:** Outlier pixels that do not have a linear behavior as described in the CCD specifications are marked as defective during the calibration procedure. These pixels are not used or only partially used during post processing and the information is restored by interpolation between the neighborhood pixels surrounding the defective pixels.

Sanborn's Camera Accuracy Testing

Sanborn's image quality criteria require consistent and homogeneous imagery devoid of response gradients and vignetting within an exposure, and unnatural tonal variations across exposures. To ensure that these criteria are met, Sanborn employs a four-step radiometric calibration and processing method. These steps are:

- **Pre-Flight Calibration:** Camera response is calibrated the day of acquisition for the ground reflectance and expected illumination conditions. The calibration process ensures maximum use of the available 14-bit dynamic range and correct color balance. An advantage of the Eagle camera is the ability to respond to changing flight conditions. Camera settings can be changed by the operator within a flight line if required to ensure quality imagery collection.

- **Atmospheric Correction:** Atmospheric correction removes any haze or atmospheric transmission loss using a Modtran4 derived correction function.
- **Sensor Corrections:** Pre-processing to remove any vignette effects producing a homogeneous exposed image.
- **Color Balancing:** Final processing includes local and global color balancing to ensure all image exposures appear to be taken at the same time with no tonal variation across seams.

Digital Aerial Imagery Acquisition

Sanborn recognizes that one of the most critical phases of this project is acquisition of the aerial imagery. Timely collection of consistent, high quality aerial imagery and related data is the foundation for generating high quality digital orthophotography and other derivative data products.

Our aerial team provides the following benefits to COAGA 2019:

- Extensive, wholly-owned data acquisition resources to ensure collection within optimal windows of opportunity;
- A fleet of eight aircraft, including high performance multi-engine and turbine-powered aircraft and one craft that is equipped with dual ports, and is capable of performing acquisition with multiple sensors;
- Five (5) large-format digital aerial camera sensors, including three new-generation Vexcel UltraCam Eagles to provide a variety of collection options, including simultaneous RBG and NIR capture;
- AGPS/IMU units to collect photo center position and direct exterior orientation data for imagery; and,
- Aircrews and photographers with extensive experience in the State of Oklahoma and surrounding region, including projects for COAGA 2015 and City of Edmond mapping services in 2016 and 2018.

Acquisition Equipment and Resources

A summary of acquisition assets available to the COAGA 2019 through our airborne data acquisition team is shown in the table below. Sanborn has sufficient aircraft and sensors to complete airborne data acquisition in Spring, 2019, with a very high level of redundancy. Any of the aircraft in the table could be tasked for the COAGA 2019's project, as needed to complete acquisition in a timely manner. The listed aircraft are equipped with gyro-stabilized mounts, computerized flight management systems, and ABGPS/IMU systems for precise photo-center positioning and orientation.

Sanborn Airborne Data Collection Assets	
Aircraft Type and FAA Registration Number	**Sensor Systems**
Multi-engine Piston Piper Navajo PA-31-325; N27693 Multi-engine Piston Piper Navajo PA-31-310; N278RC Multi-engine Piston Piper Navajo PA-31-310; N500Q Twin-Turbine Aero Commander 680W; N940U Twin-Turbine Aero Commander 690A; N690EH Single-engine Piston Cessna TU206F; N603ET Single-engine Piston Cessna TU206G; N735BT Single-engine Piston Cessna TU206G; N2326B Leptron Avenger B (UAV); N824LP DJI Inspire 1 (UAV); FA3HM9MYRM DJI Phantom 3 Professional (UAV); FA3WMPCPHC	Three (3) Vexcel UltraCam Eagle cameras Two (2) Leica ALS-70HP airborne lidar sensors Two (2) Leica RCD30 Aerial Camera Systems *(Add-on to Leica ALS70 HP Airborne Lidar System)*

Data Acquisition Planning

Sanborn has designed the project so that all imagery is acquired during the hours of approximately 10:00am to 2:00pm, when the sun angle is at a minimum of 35 degrees, which helps to minimize shadows.

Sanborn will carefully plan all missions to ensure that resulting data will be compliant with the requirements set for the project, and review our proposed flight and ground control plans with the COAGA 2019 prior to mobilizing any field or airborne resources. Proposed plans will be provided to the COAGA 2019 at least one (1) week prior to mobilization. The following table presents our proposed acquisition specifications for the project.

Imagery will be acquired at 6-inch resolution for Cities of Moore and Norman; and 12-Inch for Canadian County. Imagery will be acquired at 3-inch resolution for Edmond, Del City and Midwest City.

Imagery Acquisition Specifications			
GSD	**3-inch**	**6-inch**	**12-inch**
Proposed Sensor	UltraCam Eagle	UltraCam Eagle	UltraCam Eagle
Focal Length	100mm	100mm	100mm
Flying Height Proposed	4,732’ AGL	9,464’ AGL	18,929’ AGL
Aircraft Speed	175 kts	175 kts	230 kts
Sidelap	30%	30%	30%
Endlap	60%	60%	60%
Sensor Platform	Multi-Engine Fixed-Wing Aircraft		
Radiometry	4-band, 14-bit per channel RGB/NIR		
Acquisition Date	~ February 28, 2019-March 31, 2019		
Acquisition Time	~10am – 2pm		
Sun Angle	35 degrees or greater		
Conditions	All deciduous trees in a leaf off state to ensure minimum ground obstruction from the existing tree canopy. Free of clouds, haze, smoke, dust, or any other aerial particles that may degrade the image. Ground features free of snow and ice. All unmanaged water bodies (lakes and streams) will not be at flood levels – photo acquisition will not take place within 2 days after a rainfall of 0.5 inches or greater or within 5 days after a rainfall of 2 inches or greater.		

Flight and Control Planning

Flight planning and execution will adhere to ASPRS Draft Aerial Photography Standards. All flight and control plans will be reviewed by one of Sanborn's ASPRS Certified Photogrammetrists prior to their release. A summary of procedures and considerations in flight mission planning is as follows:

- Sanborn will prepare a digital flight line layout for the project areas using Track'Air software, taking into account the configuration of the UltraCam Eagle aerial camera, which we propose to use for this project, and the accuracy and resolutions required for the imagery and other data products under the COAGA 2019's solicitation. These parameters determine the flight altitude, the footprint of each exposure on the ground, and correspondingly, the quantity of flight lines and exposures, and ground control requirements.
- Flight lines typically extend continuously across the project area; however, lines may be optimized in order to account for terrain, areas with tall structures, water bodies, airspace restrictions, and issues related to sun angle, lighting, and shadows.
- The Vexcel UltraCam Eagle will collect all imagery with 14-bits per channel in all 4 bands – Red, Green, Blue, and Near-Infrared. Our software enables us to orthorectify all four bands simultaneously, so there is no upcharge over collection and processing of 3-band imagery to deliver a 4-band orthorectified imagery product, providing added value to the COAGA 2019, if the 4-band imagery is desired.
- The principal points of the first two and last two exposures of each flight strip will fall outside the boundaries of the area to be covered by the flight.
- In order to ensure sufficient coverage, Sanborn will plan imagery collection so at least 25% of each outermost line of images extends beyond the boundary of each area of interest.
- Forward lap and side lap will be as shown in the table above, and will be adjusted as needed to ensure collection of quality imagery in areas with unique terrain or built infrastructure considerations.
- Sanborn's flight plan will contain the following information:
  - Projected flight lines
  - Flight line numbers
  - Intended coverage
  - Approximate number of exposures
  - Flight altitude
- Sanborn will overlay the flight line layout over Google Earth imagery, and determine optimum locations for the placement of ground control points, ground checkpoints, and GPS base stations, where these items are needed. Following the COAGA 2019's approval, the control locations will be passed along to the project surveyor who will target, survey, and provide any other needed resources or information in support of the airborne acquisition mission.
- The final flight line map/photo index with photo centers will be delivered in Adobe .pdf file format, and in Esri Geodatabase format.

Resource Calculation/Acquisition Schedule

Sanborn has designed preliminary flight plans for the project and estimated that the acquisition requires six (6) full flight days, or mission days. With Sanborn's estimated weather factor of 4.79:1 (i.e., for every 4.79 calendar days there is one 'good weather' flying day), a total of 29 calendar days is required.

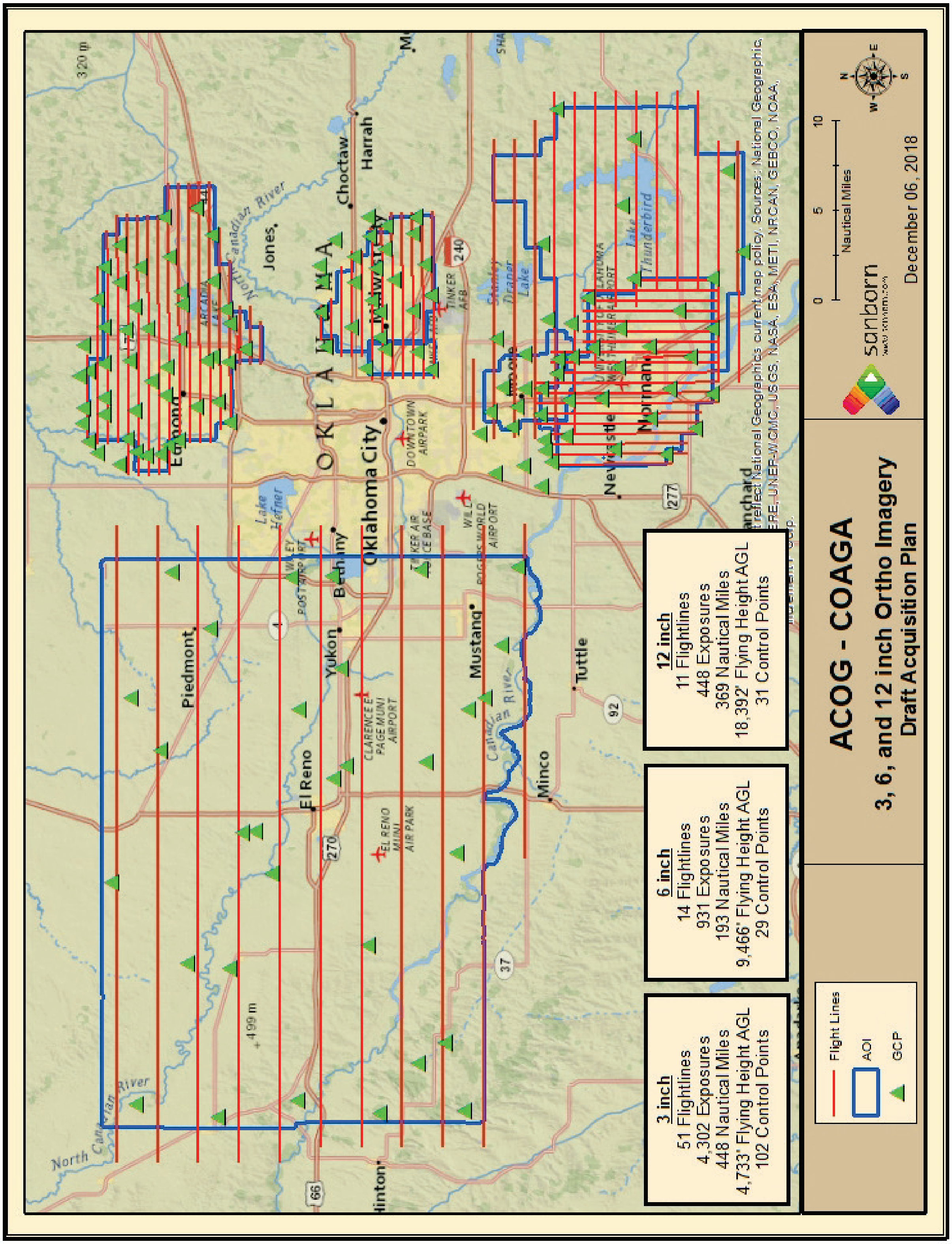
Sanborn will mobilize the necessary aircraft and sensors to ensure that all imagery will be acquired in the required timeframe with ideal leaf-off conditions (weather permitting).

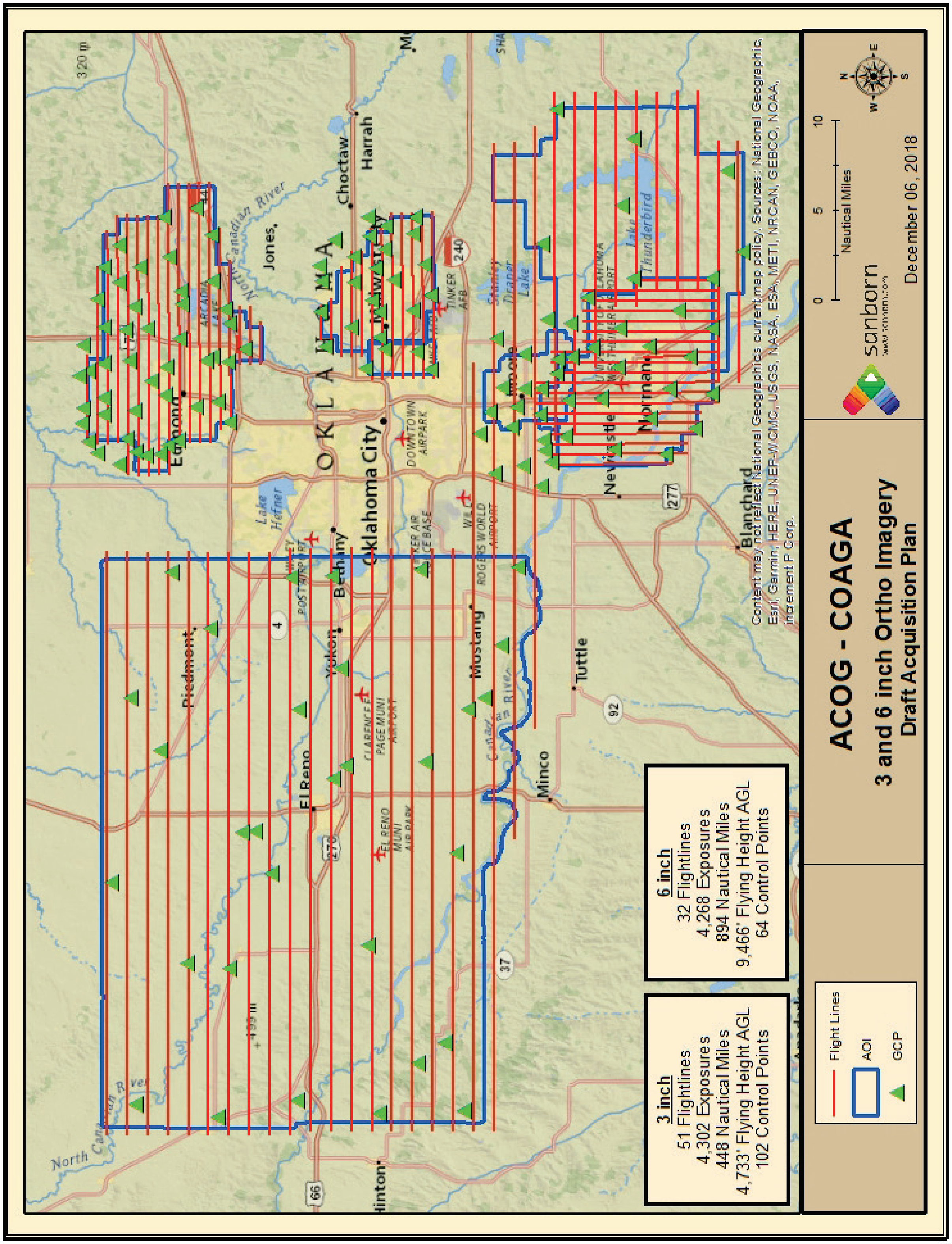
The following procedures and parameters are used for resource acquisition:

- Design Number of Flight Lines
- Estimate Flying Height
- Estimate Flying Speed
- Estimate hours of operation when the sun angle will minimize shadows and allow for maximum interpretability (greater than 35 degrees)
- Estimate the weather factor for the specified time of year

Flight (and Control) Diagrams

Sanborn has prepared preliminary flight maps for the COAGA 2019's proposed project, presented on the following page(s).


ACOG - COAGA
3, 6, and 12 inch Ortho Imagery
Draft Acquisition Plan
3 inch
51 Flightlines
4,302 Exposures
448 Nautical Miles
4,733' Flying Height AGL
102 Control Points
6 inch
14 Flightlines
931 Exposures
193 Nautical Miles
9,466' Flying Height AGL
29 Control Points
12 inch
11 Flightlines
448 Exposures
369 Nautical Miles
18,392' Flying Height AGL
31 Control Points
Flight Lines
AOI
GCP
Nautical Miles
December 06, 2018
Oklahoma City
Edmond
Norman
Yukon
El Reno
Mustang
Piedmont
Bethany
Minco
Tuttle
Harrah
Choctaw
Jones
Newcastle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894 Nautical Miles
9,466' Flying Height AGL
64 Control Points
Flight Lines
AOI
GCP
Nautical Miles
0
5
10
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
Oklahoma City
OKLAHOMA
Edmond
Jones
Choctaw
Harrah
Midwest City
Bethany
Yukon
Mustang
El Reno
Piedmont
Tuttle
Minco
Newcastle
Norman
Blanchard
Lake Hefner
Lake Thunderbird
Stanley Draper Lake
Arcadia Lake
North Canadian River
Tinker AFB
Downtown Airpark
Wiley Post Airport
Will Rogers World Airport
Clarence E Page Muni Airport
El Reno Muni Air Park

Flying Conditions/Requirements

Our aerial team will monitor weather conditions and determine when to mobilize for the aerial missions. The optimal conditions occur:

- When the ground is clear of snow
- When the deciduous trees are barren
- When the air is free of smoke, atmospheric haze, fog, and dust
- When the air is free of clouds
- When the sun angle is 35 degrees or more above the horizon
- When streams are within their natural banks

All photography will be accomplished between ~ 10:00 am and 2:00 pm to minimize shadows.

Imagery will be rejected if clouds which impact the orthoimagery product are noted, or if the sun angle is less than 35 degrees, or if there are any other conditions which do not produce consistent, high-quality photography that clearly defines ground features.

Photography is accomplished by flight crews who will be temporarily based in COAGA 2019's area in close proximity to the collection areas. We will attempt to acquire imagery in the shortest possible timeframe to minimize radiometric differences in the final image database.

Sanborn relies on a variety of sources to determine the suitability of conditions for acquisition. Our first and primary source is the flight crews and surveyors in the areas of interest. Flight crews are trained to observe and report the conditions as they see them on the ground and in flight. We will also coordinate with and defer to the COAGA 2019 if there is any question regarding suitability of conditions. Finally, there are a variety of ways to observe conditions remotely, including NOAA and NWS weather reporting stations, daily weather satellite reports, weather video cams, and a variety of public sources that can be accessed for detailed observations.

Mobilization Planning

Sanborn will perform mobilization planning to ensure that airborne data acquisition can progress in accordance with the project schedule. This will include:

- Monitoring conditions to determine when the ground is clear of snow, leaf conditions of deciduous trees, and the conditions of lakes, streams and rivers.
- Monitoring sun angle in order to determine the time ranges in which flights can be conducted.
- Monitoring weather conditions.
- Locating airports at which to stage aircraft and aircrews, and arranging for their accommodations.
- Making arrangements to access restricted airspace, if needed. Sanborn will coordinate all flight plans with air traffic control (ATC) well in advance of mobilization.
- Ensuring that all needed ground control and base stations are in place prior to the flights.
- Monitoring GNSS satellite configuration

Mission Execution

Sanborn's aircrews will be mobilized to an airport near the project. The aerial team will monitor flight conditions and determine, in coordination with Sanborn's project manager and the COAGA 2019, when to initiate imagery collection flights. Imagery will be captured for the entire project area at the required level of resolution. Mission profiles will be programmed into the Track'Air Flight Management System, which is integrated with the sensor systems on board each aircraft. This computerized system assists the aircrews with mission navigation and sensor operation, ensuring that imagery is collected in accordance with the flight plan. Aircrews are also able to mark flight lines or exposures where turbulence, clouds, or other factors that bear on the quality of the imagery may be an issue, so it can be accessed rapidly following the flight, and assessed for recollection, if necessary.

Operational Considerations

Sanborn's experienced aircrews are highly familiar with the airspace system in the region, and know how to navigate safely and efficiently within its boundaries. All flights will be coordinated with the appropriate civilian and military air traffic control authorities. Our aerial team has the relationships needed to gain access to sensitive and restricted airspace.

Sanborn's aircraft are equipped with all of the communication and navigation avionics required to operate safely in the federal airspace system. All of our aircrews are appropriately licensed and qualified, and our aircraft are operated and maintained in accordance with applicable Federal Aviation Administration (FAA) regulations at all times.

While Sanborn does not anticipate any difficulty with regards to airspace access, our aerial team is prepared to make any necessary operational adjustments should airspace changes or temporary restrictions make them necessary. Possible steps to mitigate airspace issues include use of a sensor with a longer or shorter focal length lens, in order to enable operation above or below restricted airspace ceilings, or rescheduling or reconfiguration of flights. Sanborn will provide immediate notification if any of these steps become necessary.

Post-Acquisition

Flight logs will be prepared following each mission. The pilot or system operator will prepare a flight log for each flight day containing the date, project name, aircraft used, and names of crew members. In addition, the following information is recorded for each flight line: altitude, sensor number and any other comments relative to the flight conditions. These flight logs will be submitted digitally. All AGPS, IMU, and image data will be downloaded the day of collection. Preliminary processing of the ABGPS data is performed to ensure the data is complete and produces accurate photo center coordinates.

Status Reporting

Sanborn requires flight crews to submit a daily status report by fax or email immediately after that day's operations to the Sanborn acquisition manager. The report states what occurred during the day. If the crew didn't fly, they report why. If they did fly, they report what was flown, the weather and ground conditions, and the expected image quality. In both cases, they also provide a prediction for the next day's operations.

After receiving the reports from the field, the Sanborn production office in Colorado Springs, CO, will compile the results into one daily status report to send to Sanborn's project manager. This report will be reviewed and an update will be emailed to COAGA 2019 on a daily basis.

In the past, this simple reporting system has proven highly effective. It is simple enough to not burden the flight crews, flexible enough to handle field contingencies, and effective enough to communicate the essential details to the COAGA 2019.

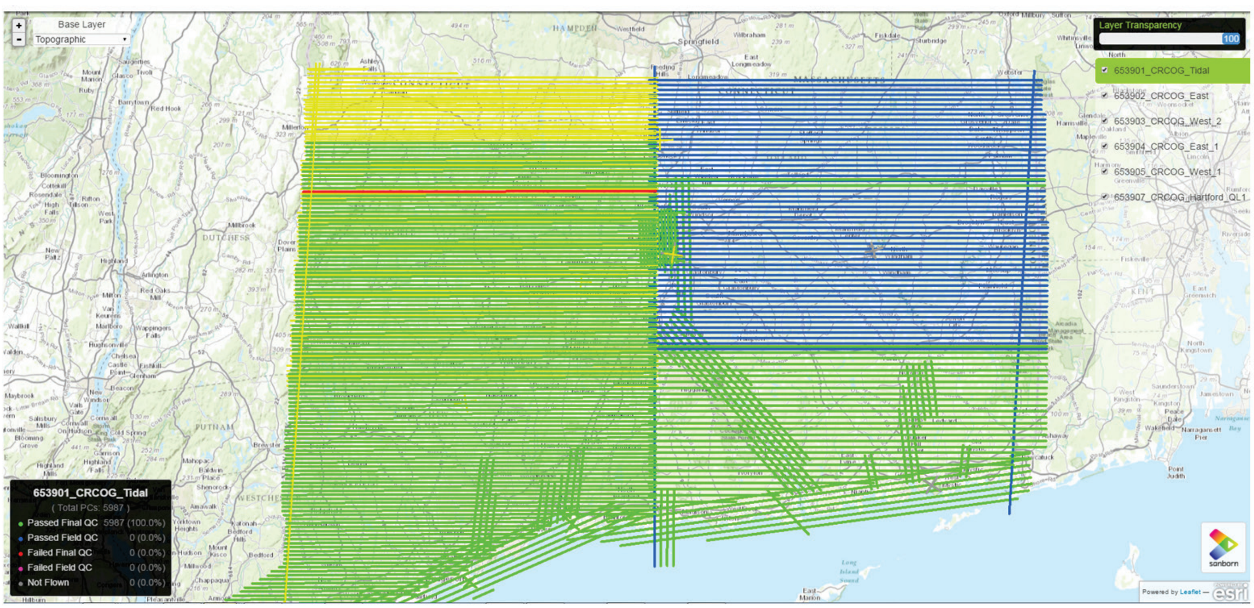
Online Flight Status Tool

Sanborn has recently developed an online status tool which would be used to report flight status during the acquisition process. The online status tool will be updated daily, and will complement the reporting information provided daily by the Sanborn project manager. The status tool will display the updated version of the flight plan shapefile(s) indicating which frames have been captured, reviewed, and/or accepted.

The COAGA 2019 can identify the specific stakeholders that they would like to have access to the online status tool. With a unique login, stakeholders have the ability to access the acquisition status at their own convenience. This tool facilitates the sharing of the project information between Sanborn and the COAGA 2019's stakeholders.

This technology will benefit this project and the COAGA 2019's project manager by:

- Providing easy distribution of acquisition status updates, alleviating reliance on email or phone calls
- Providing information in a format accessible from any internet connected device
- Providing access to multiple COAGA 2019-approved stakeholders simultaneously, which will relieve the COAGA 2019's project manager from answering calls from stakeholders regarding status.



Sanborn Online Flight Status Tool

Image Processing and Radiometry

The Sanborn Image Processing Team is responsible for receiving and processing the raw imagery data after it is acquired by the Acquisition Team in the field. The imagery and peripheral data sets will be downloaded from the on-board data storage system, backed up, and shipped via overnight courier to Sanborn's production facility in Colorado Springs, Colorado. Upon receipt of the newly-collected imagery by the production office, the digital image processing phase is initiated. The following characteristics exist in all camera systems. While each system type has slight variations, all digital frame sensors are fundamentally similar in the way imagery is recorded and processed into useable data.

Each system uses an array of Charged Coupled Devices (CCD) to record panchromatic, RGB, NIR values. Once the images are acquired by each sensor, the imagery and mission parameters are stored in a raw binary format on the flight hardware. Each sensor uses a series of portable hard drives which can be linked to the aircraft-based servers; upon landing, the imagery is downloaded to the portable drives. Once the imagery has been transferred via the portable hard drives to a production facility, post-processing begins. The array of CCD's requires post processing of each individual frame in order to mosaic together a single large format image. Each sensor type has a slightly different CCD layout, but the final frame image is a 4-band, 12-bit image.

The Image Processing Team works in tandem with the Geo-positioning Team to ensure that all collected data meets the predefined customer specifications. Once it has been determined that all data meets customer specifications, the Image Processing Team is responsible for imagery enhancement and color balancing the data. The Image Processing Team follows a well-defined work flow process that emphasizes quality control, as illustrated in the following workflow.

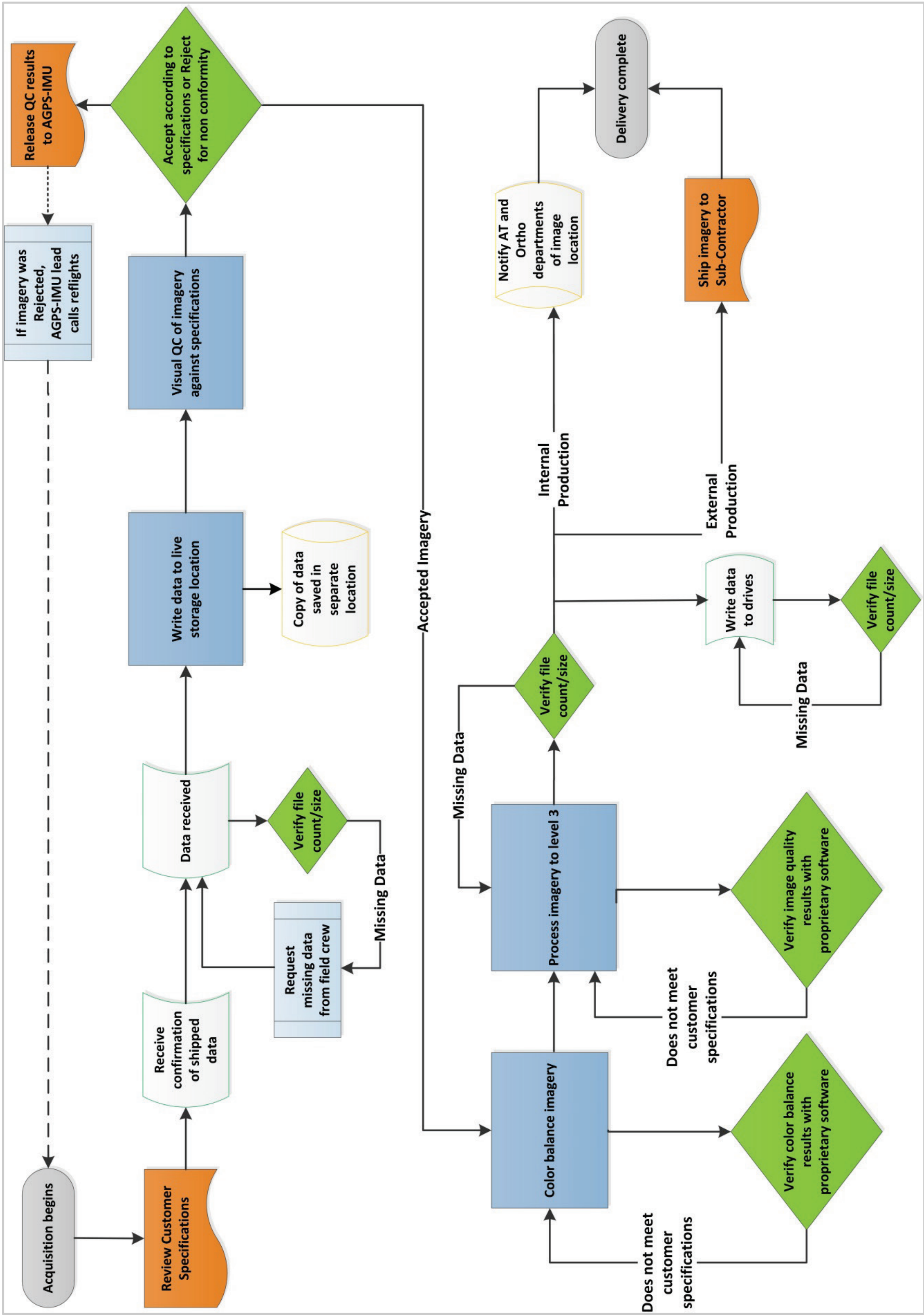


Image Processing Work Flow Diagram

Upon receiving the "raw" image data from Sanborn's flight operations, it is downloaded to the server to initialize processing in the Vexcel UltraMap software. Using UltraMap Raw Data Center, the "raw" image data is processed to a DragonFly Project file (.dfp) of the imagery which allows image processing technicians to view and manipulate each imagery mission. The .dfp file is then loaded in the UltraMap AT software in order to run Project Based Color Balancing (PBCB) on the images. PBCB uses tie-point collection which samples the histograms of all images in a block to produce a color balanced set of images. Imagery missions can be merged to provide a continuous color balance across the entire project. After PBCB is run, the .dfp file is opened in UltraMap Radiometry. UltraMap Radiometry provides tools for detailed and specific radiometric adjustments to the imagery to eliminate such things as hotspots, atmospheric effects, and haze. There are also tools to adjust the gamma, histogram levels, haze, and exposure of the imagery. All adjustments are made while the imagery is still at a 12-bit color resolution allowing for the greatest quality when converted to 8-bit deliverables. After color balancing is complete the final step is to process out the images to the desired final product. UltraMap provides options for the output type of the Images. These options in include image Mode (RGB, RGBI, CIR, etc.), resolution, file format and Bit Depth (8/16 bit).

In addition, during QA/QC, each image will be displayed and checked for completeness, radiometric acceptance, and any obvious visual problems. Any cause to reject the image will justify the need for a re-processing or re-flight of that particular image. Only after images have been displayed, checked, and accepted will they be released for use in subsequent production procedures.

Before and after Project-Based Color Balancing

Photography Quality Control

Sanborn takes every possible measure to ensure that mission planning, operational conditions, precision aerial cameras, and computerized flight management systems all work together to result in the acquisition of high quality, error-free imagery for the project. We quality check the entire imagery data set three times before accepting it for exploitation.

As each image is acquired, a snapshot of that image is visible to the aircrew on a monitor. Our photographers view this snapshot at the time of capture and then again post-mission, before sending the imagery to the office. Sanborn's photographers identify over 98% of the re-flights in the field through this QA process.

When an imagery data set arrives at the office, it is immediately backed up. Thereafter, it is processed to the final image. This processing occurs quickly, as dedicated, high-capacity workstations utilizing a distributed processing system are used for the task. After the imagery is processed, a technician reviews the imagery a third time. The technician looks for details which may not have been visible in the snapshot and confirms that the image processed correctly. Checks performed by the technicians include:

- Review of the imagery for density, contrast, hot spots, clarity, shadow and highlight detail, and overall quality.
- Technicians will also check each line of imagery for:
  - Adherence to the flight plan—the editor will review the imagery to ensure that the specified flight plan has been successfully executed.
  - GSD—the technicians will confirm that the specified GSD has been achieved.
  - Departures from flight heights required to produce the desired image scale shall not exceed minus two percent (-2%) or plus five percent (+5%)
  - Crab— Crab in excess of three degrees (3°) may be cause for rejection of a flight.
  - Tilt and Tip— Tilt of the camera from vertical at the instant of exposure shall not exceed three percent (3%), nor shall it exceed five percent (5%) between successive exposure stations. Average tilt over the entire project shall not exceed 1%.
  - Forward overlap—the forward overlap will be examined to ensure that it falls in the appropriate range for each acquisition area.
  - Side overlap—the side overlap will be examined to ensure that it falls in the correct percent range for each acquisition area.
  - Anomalies—any other anomalies that could affect the final product will be examined, such as exposures settings, pixel drop out, etc.

If the technicians identify the need for any re-flights, they immediately email the flight crew needed parameters. Our goal is to accomplish this review within three days of acquisition of the photography. Sanborn understands that unacceptable imagery will be re-flown at no additional cost to the COAGA 2019. All re-flight coverage will overlap the accepted imagery by at least two exposures, and will be captured using the same sensor type that performed the initial acquisition.

Geo-referencing

Sanborn's approach will be to utilize existing, available control points, augmented with newly surveyed ground control points where needed, together with AGPS/IMU-controlled aerial photography to accurately control the Fully Analytical Aerial Triangulation (FAAT) solution. Airborne GPS/Inertial Measurement Unit (AGPS/IMU) data will provide primary support for image positioning and orientation, minimizing the required number of ground control points required, while still enabling the creation of orthoimagery and other mapping products that conform to the accuracy standards set by the COAGA 2019 for the project.

Reference System

Sanborn will ensure that all land survey and airborne GPS/IMU data collection and processing procedures generate control coordinates that result in an aerotriangulation solution that accurately georeferences all deliverable data in the Oklahoma State Plane Coordinate System, North or South Zones (shown below). The unit of measurement will be the US survey foot.

Edmond, Del City, Midwest City and Canadian County:

- Coordinate system: Oklahoma State Plane, North Zone 3501
- Horizontal Datum: NAD83
- Vertical Datum: NAVD88
- Spheroid: GRS 1980
- Map Units: US Survey Feet

Moore and Norman:

- Coordinate system: Oklahoma State Plane, South Zone 3502
- Horizontal Datum: NAD83 (HARN) - 1993 adjustment
- Vertical Datum: NAVD88
- Spheroid: GRS 1980
- Map Units: US Survey Feet

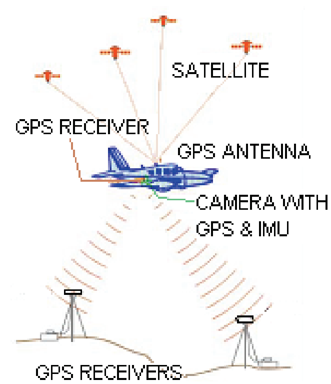
Airborne GPS / Inertial Measurement

The Vexcel UltraCam Eagle digital camera system utilizes airborne GPS (AGPS) and inertial measurement unit (IMU) data as input for sensor positioning and exterior orientation development. Sanborn's new Applanix Type 46 Non_Itar IMU's, acquired early in 2013 as part of our sensor modernization program, will be used to manage and collect data for this process. NovAtel MiLLennium DL4+ dual frequency GPS receivers collecting P-code pseudo range and L1/L2 carrier signals at a sampling rate of 2 points per second will be used in the aircraft to collect GPS data.

These directly observed exterior orientations will be combined with conventional ground control in an AT bundle adjustment. The statistics derived from the bundle adjustment will provide an accuracy assessment for ortho rectification and/or stereo compilation. The use of AGPS/IMU data has a number of benefits:

- It allows more flexibility in the selection of ground control points, making it possible to work around difficult areas such as forests, private land, restricted areas, and water bodies.
- It enhances the overall reliability of the AT solution.
- It results in bundle block adjustments of greater accuracy and homogeneity.
- Depending on the mapping products, it allows some level of reduction in the amount of ground control, enhancing production schedules.

It automatically determines all six of the parameters required for resolving the exterior orientation of each photograph and allows for more reliable and accurate results from assisted automatic aerotriangulation.



General AGPS Procedures

Sanborn's airborne GPS approach will consist of the following steps:

- Recovering or establishing suitable base station locations within the project area, as appropriate to the accuracy specifications for the project.

- Validating the bore-sighting of the camera and AGPS system. AGPS/IMU boresight calibration is performed at least twice per year. Any time the camera or AGPS/IMU is moved, a new boresight is required.
- Collecting, processing, and interpolating the AGPS data to derive camera station coordinates and rotations at each instant of exposure

During the mission planning process, Positional Dilution of Precision (PDOP) is evaluated using Trimble's Qplan or Ashtech's MPwin GPS planning software. All mission collections will be conducted with a PDOP of 3.2 or lower. The KP index is also evaluated prior to mission collection. KP index is a measurement of geomagnetic activity at the earth's surface that can greatly affect the GPS solution. Therefore, no collection will occur when the KP index is at or above 4.

Prior to the actual AGPS photography missions, Sanborn will also check the AGPS system installation. This involves:

- Checking the GPS antenna location on the aircraft
- Checking the GPS receiver to aerial camera connections
- Re-measuring the offset vector from the antenna to the camera's front lens node

Differential Airborne GPS Correction Methods

Sanborn may use one of three technologies for Airborne GPS Correction:

- **Trimble CenterPoint™ RTX™**: Sanborn subscribes to The Trimble CenterPoint™ RTX™ correction service. This service is a high-accuracy, satellite-delivered global positioning service that is available across Applanix's entire airborne mapping portfolio. The Trimble CenterPoint RTX correction service is delivered by L-Band satellite or by the Internet. This technology provides high-accuracy GNSS positioning without the use of traditional reference station-based differential RTK infrastructure, which results in more uptime, faster initialization, and hardware savings. This enables Sanborn to generate map products faster at a reduced cost. Benefits of this system include:
  - Availability: Worldwide
  - High Accuracy: Provides <4cm (1.5-inch) horizontal accuracy
  - Quick initialization: CenterPoint RTX converges to full accuracy within 1 to 5 minutes in select regions, and less than 30 minutes worldwide
  - Multi-constellation support: GPS, GLONASS, Galileo, BeiDou and QZSS enabled
  - More uptime: Work can continue through correction signal interruptions for up to 200 seconds
  - No base station required: Since a base station is not required for Trimble RTX-based correction services, losing radio signal connectivity is not a concern
- **Continuously Operating Reference Stations (CORS)**: During the data acquisition missions, multiple National Geodetic Survey Continually Operating Reference Stations (NGS CORS) that are up to 200km from the acquisition area will be logging data at 1-, 2-, or 5-second increments that will be download and incorporated when processing the airborne GPS solution. In order to ensure mission integrity, Sanborn will be operating base stations on the ground in the proximity of the project area for the duration of the acquisition flight as a backup in case of any failures or problems with the CORS system.

- **Traditional Base Stations**: Typically, at least one GPS base station will be in operation during each mission. This GPS receiver will be set on a published National Geodetic Survey control point such as the Primary Airport Control (PAC) Station. If for any reason it is not possible to set a GPS base station at a published NGS point, a temporary point will be introduced and marked near the fixed base of operation (FBO) at the airport of departure.
  - The base station receiver at the airport will be operational prior to starting airborne data collection. All crews will have their base station(s) running at least 7 minutes prior to sun angle and at least seven minutes after sun angle. This provides redundant base station data in the event of a base station failure or other unanticipated GPS issue from one crew. All GPS receivers will be set to an epoch rate of 2 Hz.

In-Flight Calibration

The AGPS/IMU system requires a seven minute "initialization" period for satellite data acquisition prior to takeoff. This seven minute time period will not begin until after the system has been started and data logging has begun. After landing and when the aircraft is stationary, the AGPS/IMU subsystem will continue to collect data for seven more minutes. This procedure ensures that the airborne GPS unit is functioning properly and the solution is fixed. The initialization and termination of the aircraft's data collection will occur as close to the airport base station as possible, but far enough from buildings to prevent multi-path errors.

The ground and airborne GPS receivers will collect data at half- second epochs for the duration of all missions. Aircraft will not be banked more than 20 degrees during data collection to prevent loss of lock with GPS satellites.

AGPS Post Processing Software

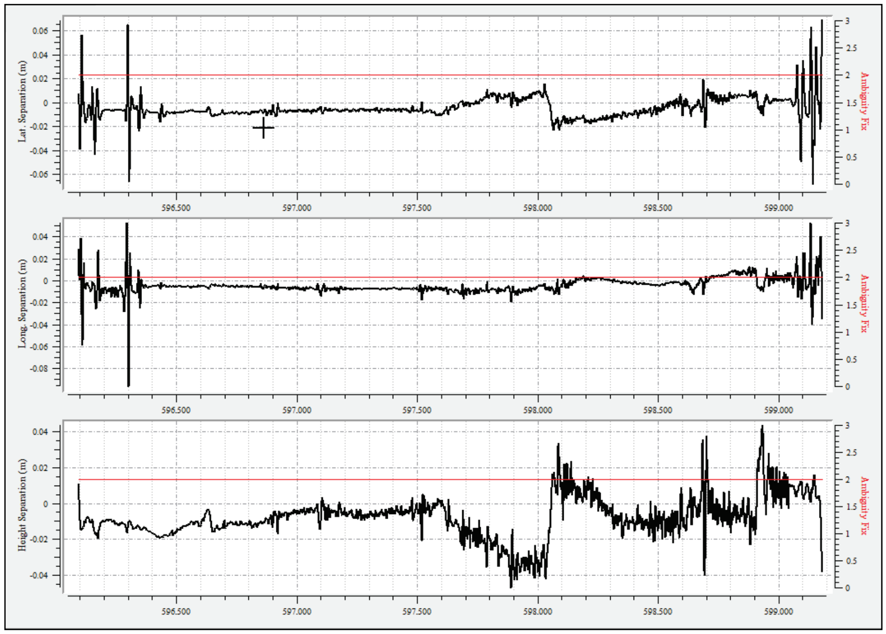
All AGPS/IMU data will be downloaded from the aircraft the day it is collected. Sanborn will use the latest version of Applanix MMS kinematic AGPS post-processing software (currently v6.2) to process all AGPS/IMU data. Sanborn has been using this software since 2008. Applanix MMS software has numerous benefits, including:

- It exports into the proper format for direct input into the Inpho Match-AT software
- Numerous visual displays are available to assess systematic errors as well as to ensure that the requisite accuracy is met

In a combination of AGPS data, the expected accuracy of the orientation of the photo exposures will be 0.10 meters in position and approximately 20 to 30 arc seconds in tilt, roll, and heading. Once a final solution is achieved, the photo center coordinate positions will be exported in the project coordinate system in preparation for use in aerial triangulation (AT).

Airborne GPS QA/QC

Sanborn rigorously checks the quality of the processed airborne GPS and INS data before implementing it into the bundle block adjustment. The kinematic data are processed from a minimum of two base stations, and the solutions are compared. This procedure verifies the integrity of the base station coordinates and elevations. Each processing session is computed in both the forward and reverse temporal directions. The comparison of these solutions provides insight into the quality of the kinematic ambiguity resolution. The below figure illustrates a high quality combined solution - positional information predominantly within the range of 4cm.



Once a final solution is achieved, the photo center coordinate positions will be exported in the project coordinate system in preparation for use in aerial triangulation (AT). Sanborn will supplement the final AT report with a section addressing the AGPS/IMU component of the acquisition. The information provided will include at a minimum:

- An analysis and write-up of the AGPS/IMU collection procedure, processing, and results
- An index identifying each image, corresponding digital file name, and image acquisition date and time in Esri .shp format.
- All photo centers (X,Y,Z) and the IMU unit rotation values

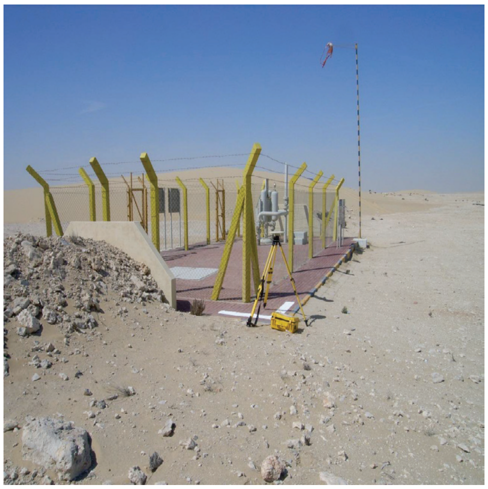
QuickView Web Service

Sanborn is offering to provide early access to georeferenced imagery via our QuickView service, which provides our clients with the ability to see captured imagery ***within 14 days of being flown***. This service is presented as web-based application or a URL that can be used in ArcGIS Desktop or other free, open source software for GIS that consumes OGC web map services. Access to the imagery allows users to begin interacting with the imagery in a timely manner and represents a quick look at recently captured images. The QuickView Service provides the following benefits:

- Preliminary quality control check to ensure there are no major issues with the image capture across the project
- Quick access and viewing via web services
- Refreshed imagery service within 14 days of each flight mission
- Acquisition progress monitored throughout the flight season

Ground Control Surveys

While Airborne GPS and IMU technology will serve as the primary means for geo-referencing, a framework of ground control is needed to serve as checkpoints and to enhance the control solution. Aerial control or ground checkpoints will be photo-identified or targeted as needed by Sanborn. New control will be established where control from previous projects is unavailable or unrecoverable. Mr. Steve Wood, registered Oklahoma PLS, will perform and certify the ground control survey.



Example of Photo identifiable control

Example of targeted control

New Control

Where new control is needed, Sanborn's survey team will perform reconnaissance to determine optimal locations for its placement. Criteria for selection include:

- **Suitability**—for photogrammetric ground control, including good contrast between the ground surface and target material, and a flat ground surface.
- **Safety** – Protection or shielding of targets from disturbance or destruction. Safety of equipment and personnel
- **Recoverability**—ease of recovery
- **Accessibility**—for occupation by GPS and other surveying equipment
- **Locality**—within public rights of way or easements or on public property, where feasible
- **Compatibility**—potential conflicts with future development, including the construction of new highways
- **Visibility** – locations that allow an open and unobstructed view to the sky

Monumentation

Newly surveyed points will be semi-permanent, and will either be a 12-inch spike, or a PK nail with an aluminum washer. The intent of these survey monuments will be to meet analytical aerial triangulation and check point requirements only.

Targeting

Using control point coordinates and/or shape files along with GIS base layers, a location map will be generated for each control point. Survey field technicians will use these maps to reach the vicinity of each point, and then use either mapping grade or RTK GPS units to pin point the monument location. The target placement will be documented with at least three photos: a close-up of the monument, a full frame of the target, and landscape features surrounding the target.

All targeted ground control points will be paneled with material of sufficient color and size to enable ease of identification in the aerial imagery, and use in the aerial triangulation process. Targets may be of an “L”, “V” or "X" shape. Painted targets will be placed using pre-fabricated templates and water-based paint. Plastic target material will be used on unpaved surfaces.

Control Specifications

All GPS surveys will meet the accuracy standards of at least order C-2-II as defined in “Geometric Geodetic Accuracy Standards And Specifications For Using GPS Relative Positioning Techniques”, Federal Geodetic Control Subcommittee, August, 1989. Accuracy will be reported according to the “GEOSPATIAL POSITIONING ACCURACY STANDARDS Part 2: Standards for Geodetic Networks developed by the Federal Geodetic Control Subcommittee (FGCS) and the Federal Geographic Data Committee (FGDC)”, 1998.

Surveying Methods: Horizontal and Vertical Control

A GPS Static and Fast Static control network forms the backbone of all location surveys. Sanborn has extensive experience in designing, processing, and adjusting large control networks, and with the coordinate systems on which they are based.

Sanborn has reviewed the COAGA 2019’ requirements for survey control, and will ensure that survey operations result in the establishment of control that meets these specifications. A high level of redundancy will be maintained between baselines on all primary networks. Reliability of point positions that have redundant base lines and can be adjusted within a network are stronger than points observed using non-redundant RTK techniques.

Sanborn will submit a control plan prior to proceeding with fieldwork that shows the location of stations to be observed with baselines to be observed during each session. Once targeting is complete, Sanborn will design a final control network which includes all new monuments as well as sufficient HARN monuments to hold as fixed points. Any network or sub-network in a survey will consist solely of independent, non-trivial baselines. Only processed baselines that have fixed ambiguity resolutions will be included in a network.

GPS Data Acquisition Techniques

Static or fast static survey observation methods will be implemented, using differential dual-frequency GPS units to provide coordinates of the new points. All observations will be conducted with a minimum of 4 observable satellites and maximum PDOP of 7. Data for fast static sessions will be collected for a minimum of 10 minutes at a sampling rate of 15 seconds. Wherever service is available, the Virtual Reference System (VRS) will be used to survey new control points. VRS surveys use CORS station corrections transmitted to the rover receiver. All field notes, sketches, adjustments, positional closures, and electronic files for all control and photo control GPS network points will be submitted in the final survey report.

Each new control point will have two or more independent station occupations. Independent occupations will have tripods reset and re-plumbed between sessions. Sessions will be separated by at least twenty (20) minutes.

All GPS surveys will meet the following minimum accuracy standards:

- Independent observations on new control points must agree within 0.09-foot in X and Y
- Observations on existing control of a higher accuracy must agree with the published coordinates within 0.09-foot in X and Y
- Independent observations on new control points must agree within 0.16-foot in Z
- Observations on existing control of a higher accuracy must agree with the published coordinates within 0.16-foot in Z

Antenna Setup—Sanborn will measure the antenna height twice at each setup: once in meters and once in feet. The two measurements will be reduced to a common unit system and compared in the field before leaving the station. This approach eliminates the possibility of observing an incorrect instrument height.

Baseline Processing—all baseline vectors will be post processed nightly using Trimble Business Center™ 3-dimensional adjustment software. Fixed bias, double-difference solutions will be determined for all selected baselines. Baselines that do not produce an acceptable solution will be discarded and re-observed on the following day.

Loop Misclosure Analysis—if closed loop surveys are implemented, loop misclosures for all figures in the network will be computed and analyzed on a daily basis. They are the first major indicators of quality, and will be tabulated and compared with the FGCS guidelines. Misclosure table will be included in the Final Survey Report for quality assurance purposes.

GPS Network Adjustments

Minimally Constrained (Free) Network Adjustment (if closed loop surveys are implemented)—After each day of fieldwork, the complete set of quasi-independent (nontrivial) baselines will be combined in a rigorous, minimally constrained, least squares adjustment. To facilitate the adjustment, the geodetic latitude, longitude, and ellipsoidal height of one existing station will be held fixed.

Sanborn will use Trimble Business Center™ or similar software, which is a three-dimensional least squares adjustment package. The variance-covariance terms from the baseline solutions will be scaled to ensure realistic observation weighting. The estimated (*a posteriori*) reference variance will be tested using the chi-squared test while the Tau-maximum test will be used for outlier detection. These tests are a direct form of quality control. Baseline component residuals will also be carefully examined.

Sanborn's approach allows for continuous quality assessment, which ensures the attainment of the required accuracy specifications. Analysis of the quality of the network will be based on these criteria:

- **Accuracy Classification**—all directly connected 95 percent relative error ellipses from the minimally constrained adjustment will be analyzed. This examination ensures maintenance of the required internal (relative) spatial accuracy. The network will be deemed acceptable when the relative positional accuracy between all pairs of stations does not exceed Second Order as defined by the FGCS.
- **Station Confidence Regions**—the station confidence regions will also be computed via the minimally constrained least squares adjustment. Examination of these results will reveal the expected horizontal accuracy of each station. Given achievement of the proposed FGCS relative positional accuracy, the final horizontal coordinates of the ground control will be more than sufficient to support the accuracy requirements for this project.

Survey Report

Upon completing the ground control phase, Sanborn's ground control team will prepare and submit a Final Survey Report in .PDF format. At a minimum, the report will provide the following information:

- Executive summary of the survey and its results
- The location and extent of the network
- A narrative description of all aspects of the surveys
- Equipment and software details
- Tables summarizing the GPS misclosures (if closed loop method surveys are used)
- Results of the minimally constrained (free) adjustment and the formal classification of the network in terms of the relative spatial accuracy
- Results and associated analysis of the constrained least squares adjustment (if closed loop method surveys are used)
- Final coordinate listings
- A network diagram, showing all stations and the measured quasi-independent baselines
- Reference sheets for all ground control points

Permissions, Public Relations and Safety Issues

Sanborn is aware of potential concerns that some members of the public may have regarding field survey operations. Sanborn will ask the COAGA 2019 for a letter explaining the intent of the survey that can be referenced in the event of queries from the public. All field personnel will dress and conduct themselves in a professional manner. Sanborn will conduct field operations during daylight hours, and observe all laws and regulations pertaining to operations in public rights-of-way, as well as entry to public or private property.

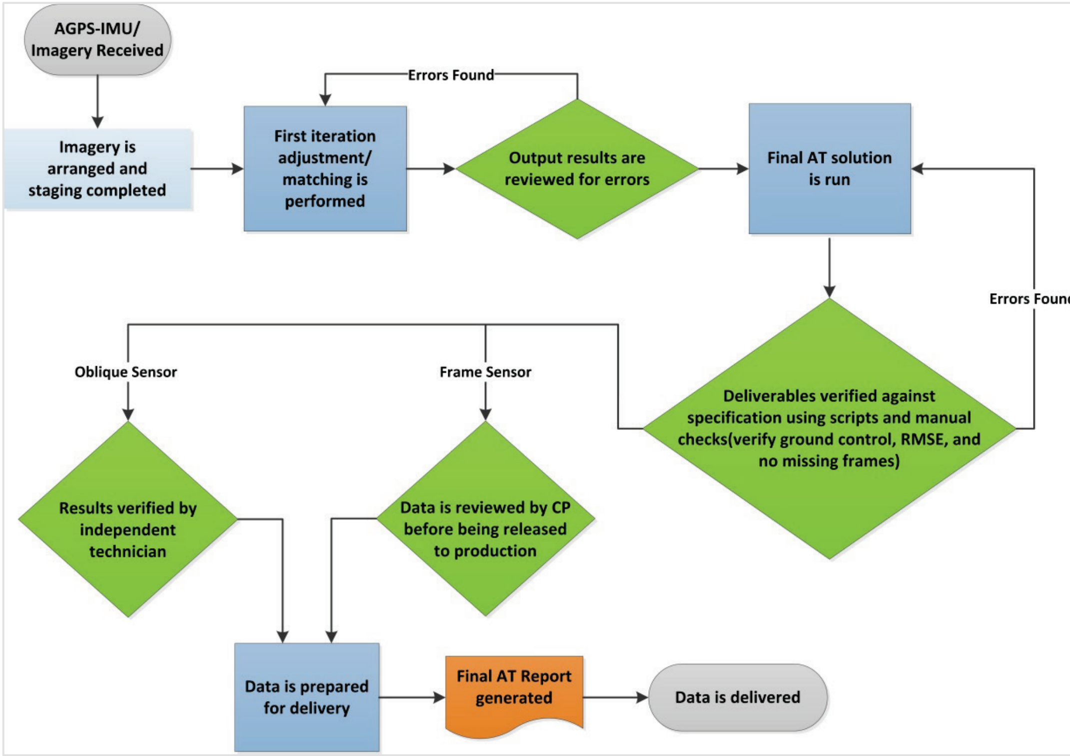
Ground Survey QA/QC

The control survey will be characterized by extensive quality control mechanisms, for example:

- Dual instrument height measurements using different units of measure, or fixed-height tripods.
- Use of redundant, quasi-independent GPS baseline in all loops; loop misclosures, (if closed loop method surveys are used)
- Least squares adjustments and statistical evaluations, (if closed loop method surveys are used)
- Use of multiple well distributed existing horizontal and vertical control points as the basis for the new network(s)
- Independent review and checking of all computations
- Supplementing GPS surveys with conventional survey techniques using electronic traversing (total stations) and digital leveling for more precise vertical control.
- Full reporting of all results and the inclusion of all computations, field logs, solution printouts, and any other pertinent information provide quality assurance.

Digital Aerotriangulation (DAT)

Once the processed imagery, ABGPS/IMU, and ground control survey data become available, Sanborn's next step will be to complete Aerial Triangulation (AT). Carefully developed and refined procedures will be followed, as the AT solution is the foundation for the accuracy of all derivative data products created from the imagery. Each stereo model will contain between 60 and 120 pixel match points to ensure that the relative accuracy and measurement integrity of the entire block of imagery is achieved. Sanborn's procedure consists of the use of a fully automatic pixel-matching routine, followed by a supervised, manual point selection, introduced strategically where automated routines have difficulty matching pixels (shadows, water, dense trees, etc.). A flow diagram outlining Sanborn's aerial triangulation approach is shown below, and described in the following paragraphs.



AT Work Flow Diagram

Assisted Automatic Aerial Triangulation (AAAT)

AAAT is a refinement of conventional AT in which airborne GPS/IMU data are used for the direct measurement of the position and orientation of every exposure in the photogrammetric block. These data result in highly reliable automatic tie point and pass point measurements, because the directly observed exterior orientation data prevents divergence of the solution. The AAAT process improves upon conventional (manual) aerial triangulation by providing numerous automated tie points and pass points. Sanborn will automatically measure seven or more tie points and pass points in each of the standard Von Gruber locations. The automation of manual point observation within the AT process introduces significant efficiency when adjusting large contiguous blocks.

The benefits of softcopy-based AAAT include:

- Alleviation of the need to perform manual pugging and observation of control points, tie points, and pass points.
- Much greater productivity, a factor that is crucial to schedule adherence and minimizing cost to the client.
- Improved accuracy, because the procedure yields many more tie points and pass points than could be practically observed by manual means.

Sanborn will use Inpho's Match-AT software to perform AAAT. On the market since 1996, and in its current version, offering what we believe to be the most evolved aerotriangulation solution available, Match-AT has a proven track record on projects of similar size and scope. The graphical display of adjustment statistics via this software is a highly valuable aid for analysis and quality control. Verification of results and measurement of ground control and check points will be performed using the Match-AT module as well. Match-AT includes bundle block adjustment module which performs least squares block adjustment after automatically matched points are generated and manual measurements are completed. Software has built in tools to flag and eliminate blundered observations.

The benefits of using Inpho's Match-AT software include:

- Match-AT enables the AT technician to use refinement to enhance the matching of a selected point in neighboring images during the mensuration of control and supplementary tie points. Sub-pixel accuracy is achieved on a routine basis.
- Match-AT provides a seamless digital environment because the AT result (namely, the final bundle block adjustment result) is applied directly, yielding single photo external orientations and absolute orientations, which can be used immediately in photogrammetric data capture and orthophoto by using Match-AT's export functions to convert data to be used in data capture and orthophoto production modules.

Absolute Accuracy Check Points

True verification of accuracy requires the use of independent check points – specifically, ground control points withheld from the AT process and used as checks after the initial adjustment. To meet statistical criteria via a sufficiently large sample, Sanborn typically withholds a minimum of one-fourth of the ground control points to be used as check points to verify the quality of the AT adjustment. Since AGPS/IMU will be relied upon as the primary element of control for this project, ALL ground control points may be withheld in order to generate an RMSE for all ground control against an independent AGPS/IMU solution. This process validates the AGPS/IMU as a stand-alone solution for meeting the specified project accuracy. A final AT adjustment will then be made incorporating all of the ground control to arrive at the best possible coordinates for subsequent photogrammetric operations.

Accuracy Standards

At a minimum, the fit to horizontal and vertical ground control of the digital analytical aerotriangulation solution will meet the following criteria, as required by the RFP:

Ortho and Planimetric Mapping Standard Product		
Product GSD (cm)	**Product Accuracy** (RMSEx, RMSEy) (cm)	**AT Accuracy** RMSEy (cm) and RMSEy (cm)
15	30	**15**
7.5	15	**7.5**
ASPRS Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0. – November, 2014)		

Aerial Triangulation QA/QC

The quality of the aerotriangulation solution is proven by low values of the error residuals in the least squares adjustment. Very low values in the residuals indicate that the ground control is free of survey errors because it fits the photogrammetric measurements. The quality control steps outlined below will be followed to help ensure the best quality adjustment. The full and complete documentation of the quality control procedures and results will be presented in the Final AT Report.

- The project boundary will be identified to ensure that triangulation coverage includes the entire project area.
- Checkpoints will be used and evaluated as previously discussed above
- Intermediate triangulation results will be thoroughly reviewed by the Lead Technician and the Data Processing Manager.
- Final triangulation results will be thoroughly reviewed by the Lead Technician, Data Processing Manager, and Production Manager.

Aerial Triangulation Report

Upon completion of all AT adjustments, Sanborn will submit a Final AT Report in .PDF format, with relevant portions in ASCII format as required by the COAGA 2019. This report will provide a narrative description of all aspects of the AT phase, tabular information for ground control and check point results, and appendices, which include documentation of the full AT solution. The Final AT Report will include the following information:

- An executive summary of the aerial triangulation (AT) and its results
- A narrative description of all aspects of the AAAT and AT bundle block adjustments
- A basic description of the project including ground control, flight planning, aerial imagery, and the airborne GPS observations and results
- Equipment and software details
- A description of the AAAT procedures and results including any geodetic considerations such as the use of a Local Rectangular System
- Results of the preliminary check point adjustment, the constrained bundle block adjustment, and the formal classification of the AT in terms of its accuracy
- Raw measured fiducial coordinates for each photo image in the photo coordinate system
- Raw measured control points and pass points in the photo coordinate system
- Adjusted control points, pass points, photo centers and residuals in the NAD 83(2011) SPCS coordinate system with NAVD88 elevations
- Standard deviation of the adjusted control point, pass point measurements, and airborne GPS photo center coordinates
- Photo orientation parameters (X,Y,Z, omega, phi, kappa) for each photo image
- Camera focal lengths used in adjustment
- Documentation of the weighting strategy used for ground control points and airborne GPS coordinates
- Final coordinate listings and other associated data in an Excel spreadsheet

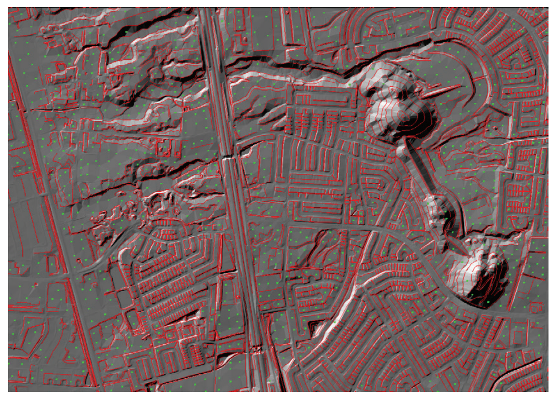
Elevation Modeling

The orthorectification process requires a digital elevation model (DEM) as an input. The quality needed depends upon the accuracy and resolution requirements of the project. A DEM that is out of date or of insufficient resolution may cause a variety of geometric inaccuracies in the orthophoto image, including distortion of the image or unsightly, visible smearing. Additionally, bridges, flyovers, and certain other elevated features require special enhancement of the DEM in order to ensure that those features are modeled correctly and the orthorectification is accurate in those areas. The need for contours calls for enhancement of the DEM into a digital terrain model (DTM) through the addition of breaklines at significant terrain breaks, and supplemental spot elevations in key locations.

The source DEM for rectification will be developed by one of the following methodologies:

- Update Existing DEM
- New Auto-Correlated DEM
- New Lidar DEM

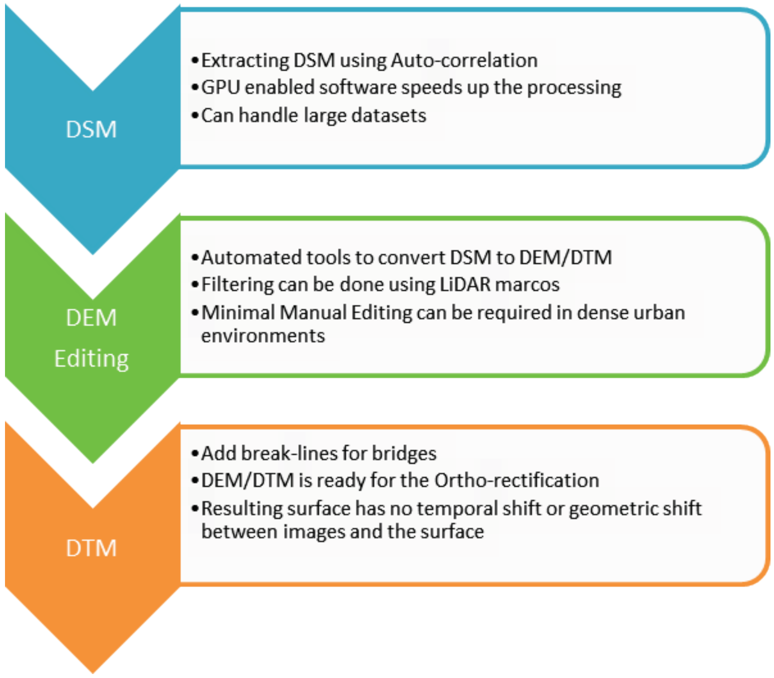
DEM Source Review



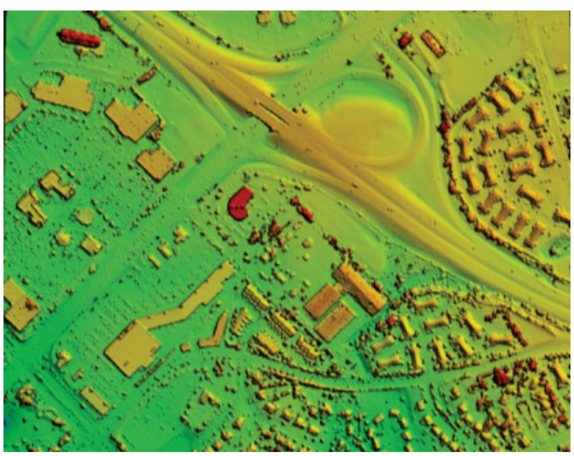
If existing, the COAGA 2019's existing DEM will be photogrammetrically reviewed using the information from the 2D and 3D change detection processes to rapidly locate areas of significant change that would induce smearing or distortions in the orthoimagery. Sanborn will update the DEM in these areas, and ensure that updated change areas in the DEM transition accurately and smoothly into unchanged portions of the terrain surface. Sanborn reserves the right to create an all-new DEM for this project if the change detection process reveals that it is more cost-effective to do so.

Masspoint Autocorrelation

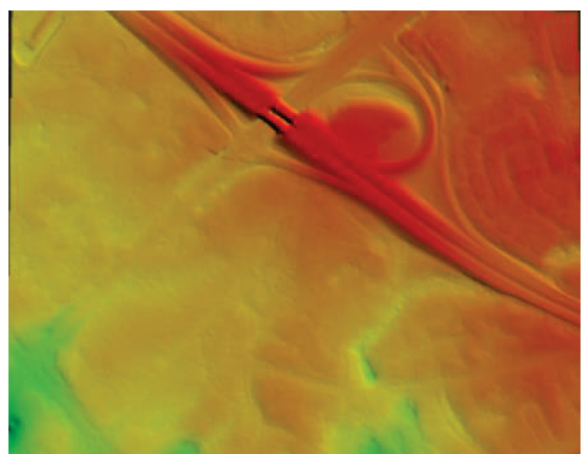
Sanborn will use autocorrelation techniques to rapidly and automatically generate masspoints in areas of the DEM requiring major revision, or to create a new DEM. This process is performed using SimActive Auto-Correlator 3D software. SimActive is graphics processing unit (GPU) enabled software that can extract masspoint DEM data from digital aerial images five times more efficiently than traditional auto-correlation engines, and to a higher degree of accuracy. SimActive then filters these points to create a very precise masspoint grid for the entire model, or within a predefined collection boundary. The software creates masspoints with an accuracy of approximately 1/10,000 of the flying height at which the aerial imagery was acquired. Surface modeling parameters will be tailored to the terrain type(s) in the project area to ensure creation of a DEM of sufficient resolution to support accurate orthorectification and contour generation. The below figure diagrams the autocorrelation process.



Mass point spacing used for the production of orthoimagery is a function of the map scale and terrain type, and whether the DEM is generated manually or automatically using softcopy techniques.



DSM (Digital Surface Model)



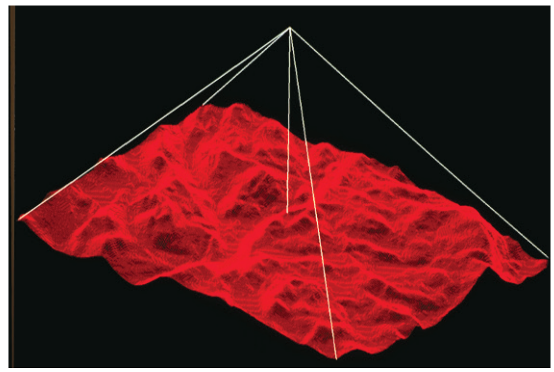
DTM (Digital Terrain Model)

Interactive Photogrammetric Editing and Enhancement

Editing of the DTM's and interactive extraction of any additionally needed masspoint or breakline data will be performed in a stereoscopic environment by Sanborn's experienced photogrammetric technicians using DAT/EM digital photogrammetric workstations. DAT/EM software provides a full set of commands that lets operators display, enhance, and manipulate stereo graphics data in a raster environment. The aerial imagery serves as a backdrop for the vector design file. This stereo superimposition technology (terrain or planimetric features traced in vector form directly over the top of stereoscopic imagery displayed on the computer monitor) ensures accurate horizontal and vertical positioning, and complete collection of all extracted features.

DTM's will be enhanced to correctly model the ground to an accuracy level sufficient to support the production of orthoimagery in full conformance with the COAGA 2019's acceptance criteria.

DTM Compilation QA/QC



Sanborn's QC of the DTM data will involve reviews for completeness (coverage, gaps), as well as duplicate points and other anomalies, such as spikes from points that are above or below the actual terrain surface. Masspoints and breaklines will be "draped" over the new imagery in a 3D stereoscopic environment to ensure that all point data is on the ground, independently verifying that all needed changes were made, and that any new data was captured correctly. Checks will be made into adjacent stereo models to ensure that breaklines are tied and continuous, and that redundant masspoint data isn't collected at model edges.

All compilation data is tied to the mapping datum as determined by the ground survey and AGPS/IMU data. Each stereo model is referenced to an AT solution. It is imperative that the ground survey and base station data for the generation of AGPS photo positions be in the correct projection, coordinate and unit system prior to performing AT or compilation.

The following quality control measures also help to ensure the accuracy and consistency of the final DEM:

1. A set of work instructions will be created detailing the work procedures that will be performed on the project.
2. The technicians will validate final ground control files from the aerial triangulation adjustment.
3. A supervising technician will review a sample of the DEM models on an interim basis during production to ensure the data is being collected correctly.

Lidar DEM

If new lidar is acquired, the process for generating the DEM is detailed in the lidar section following the Planimetric Option section below.

Ortho Imagery Processing

The creation of ortho imagery involves a number of important steps, beginning with the actual orthorectification, which corrects the geometric distortions inherent in digital aerial imagery, and turns it into a true map product. The process also involves mosaicking, and a variety of radiometric corrections, which turn the numerous individual photo images into one seamless database, with uniform, pleasing, realistic color characteristics. After it has been quality-controlled and any needed corrections made, the database is tiled to the client's specifications, and written out in the desired compressed or uncompressed image file format(s) for delivery.

Orthophotography will be produced at 6-inch resolution for the Cities of Moore and Norman, 12-inch resolution for Canadian County, and 3-inch resolution for the Cities of Edmond, Del City and Midwest City.

Pilot Project

Sanborn understands the importance of completing and receiving approval for a pilot project prior to proceeding with full production. We feel this is especially critical in orthoimagery programs, which by their nature call upon us to address aesthetic elements, as well as the quantifiable technical requirements of our customers. Therefore, we will work closely with the COAGA 2019 during the project initiation phase to obtain feedback on what your ideal is for the appearance of the imagery in terms of color characteristics, and submit pilot data samples for final approval before completing the remainder of the project in order to ensure that all standards and specifications set for the project will be met. Delivery of the pilot project will take place following completion of aerial data acquisition and digital aerotriangulation. Changes requested by the COAGA 2019 subsequent to pilot project, delivery and final approval will be addressed on a case-by-case basis. Once full production has been started, a significant change requested by the COAGA 2019 will impact the project scope and schedule, and could be subject to a formal change order. Problems or errors apparent in the final deliverable will be corrected by Sanborn if they do not conform to previously approved submissions.

Orthorectification

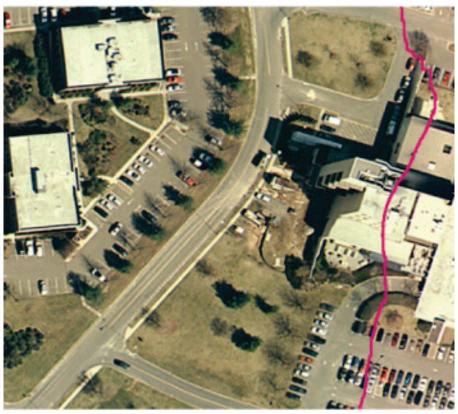
Sanborn uses a highly sophisticated, proprietary software package for orthophoto creation, which is one of the most robust and feature-rich automated digital orthophoto production software suites in the industry. The proprietary system draws upon digital elevation/terrain models (DEM/DTMs), digital sensor information, digital aerial imagery acquired for the project, and aerial triangulation (AT) data to rectify each digital image. The rectification corrects for inherent geometric distortions in the image that are caused by terrain variance, earth curvature, and camera orientation in relation to the ground. The terrain surface used by Sanborn's software is in the form of a triangulated irregular network (TIN), not a regular grid DEM or DTM. The TIN provides a more accurate representation of the terrain surface. The TIN eliminates waviness around sharp terrain breaks, such as steep embankments, road edges, railway grades, and hydrographic features, as seen by comparing the rail lines in the pictures above.

The ortho processing software uses the cubic convolution sampling technique, which yields high accuracy and excellent aesthetic quality. Cubic convolution is the industry standard algorithm for the rectification of digital orthoimagery. It relies on a 4 x 4 (16-pixel) kernel and a cubic algebraic function.

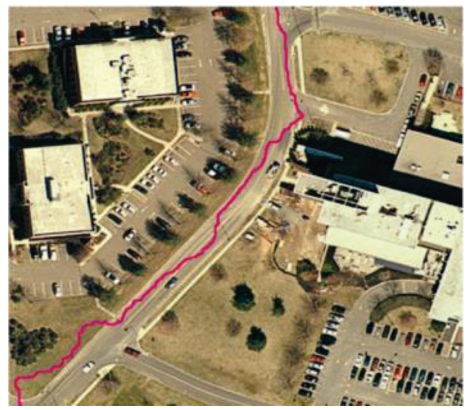
Sanborn has also developed methods and procedures that allow for the processing of the RGB color and near infra-red (NIR) bands within a single rectification. One of the greatest advantages of digital cameras systems is the ability to collect co-registered multi-spectral imagery. Because of this camera design, Sanborn can bring a 4-band image into our software and complete single-step aerial triangulation, orthorectification, and post processing. Prior to this process and the new digital camera technology, imagery providers had to collect RGB and NIR imagery on two separate flights, and perform aerial triangulation and orthorectification twice, doubling the effort, cost, and time to deliver the NIR product. Sanborn believes this new process provides an exceptional value to the COAGA 2019, as we will do not charge additional fees for collection, orthorectification, and delivery of the near-infrared data.

Mosaic Processing

Sanborn uses a unique mosaicking process that performs pixel matching along a seam line at ground level. This virtually eliminates image distortions caused by above ground features mosaicked from two adjacent photographs. As part of the mosaicking workflow, experienced imagery technicians review the seams between orthophotos to ensure that adjacent images edge match correctly. The seaming routine in Sanborn's proprietary ortho processing software avoids elevated structures so that buildings are viewed from only one source image.



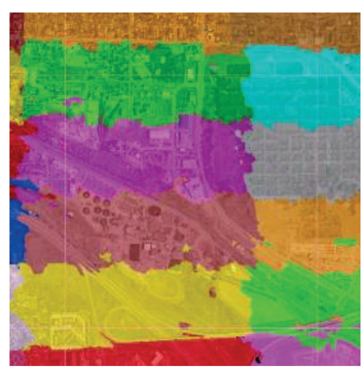
Orthophoto without intelligent seams.



Orthophoto mosaic with intelligent seams.

Seamline Generation

Sanborn's production process allows for seamline generation and a seamline deliverable, if desired by the COAGA 2019. The following illustration displays how image chips are used to make a larger mosaic. Each color within this sample represents image chips that are mosaicked together to make a single homogeneous image.



One imagery tile with eighteen contributing exposures

Sanborn tracks each image throughout the production process for the metadata requirements. This same information will be applied to the attribution of the seamline database.

Radiometric Balancing

Sanborn's image quality criteria require radiometrically homogeneous imagery that is devoid of response gradients and vignetting within an exposure, and unnatural tonal variations across exposures. A four-step radiometric calibration and processing workflow is followed to ensure that these criteria are met:

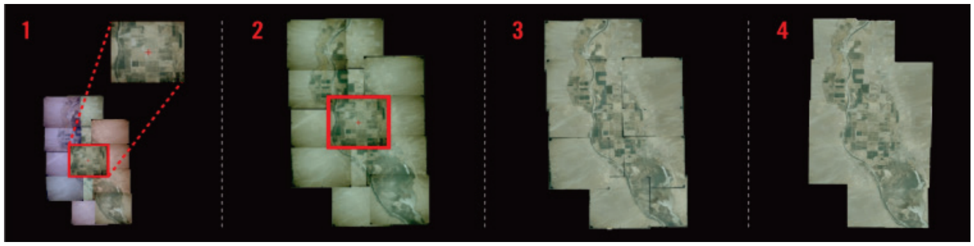
1. **Pre-Flight Calibration:** Camera response is calibrated the day of acquisition for the ground reflectance and expected illumination conditions. The calibration process ensures maximum use of the available 14-bit dynamic range and correct color balance.
2. **Atmospheric Correction:** Atmospheric correction to remove any haze or atmospheric transmission loss using a Modtran4 derived correction function.
3. **Sensor Corrections:** Pre-processing to remove any vignetting effects, resulting in a homogeneously exposed image.
4. **Color Balancing:** Final processing includes local and global color balancing to ensure that all image exposures appear consistent, with no tonal variation across seams.

Final Color Balancing

Sanborn will use tone balancing to even bright and dark areas on the imagery that are caused by changing lighting conditions , such as variance in sun angle, over the duration of the imagery acquisition process. Our procedure enables us to compute an average intensity value for each input image, and ensure that the corresponding output image retains the same average intensity, but with corrections for common photographic problems such as vignetting and uneven exposure. Once dodging has been completed, color balancing is continued using a proprietary color balancing software tool. This sophisticated tool enables technicians to use an intuitive and interactive methodology to specify the radiometric target characteristics of the final product, allowing the user to specify the radiometric properties of the final orthoimagery using a "what you see is what you get" interface, and also to match easily to client specified target characteristics. The COAGA 2019 can provide digital imagery samples as a target, and the color balancing tool will match the characteristics of the target image.

A secondary function of the color balancing software is to automatically adjust artifacts that typically lead to radiometrically non-homogeneous orthoimagery. This process is particularly important in regional areas with high reflectance, such as water. After selecting mosaic boundaries automatically or manually and defining blend types, either by default or individually, the mosaicking process runs in a batch mode. During the process, the final photos are tone balanced for optimal viewing and seamless mosaicking.

The following images show how this process can provide different radiometric values from the same source imagery based on the selection of different color targets. It is this process that will allow Sanborn to auto-match the radiometry of the prototype signature areas provided by the COAGA 2019. Sanborn will ingest the COAGA 2019's approved prototypes in stage one of this process to produce the final orthoimagery with similar characteristics. Global tone matching and seamless mosaicking will provide consistent image quality output over the entire project area.



Methods and procedures used in order to ensure a seamless orthoimage database with no discernible differences between adjacent images include:

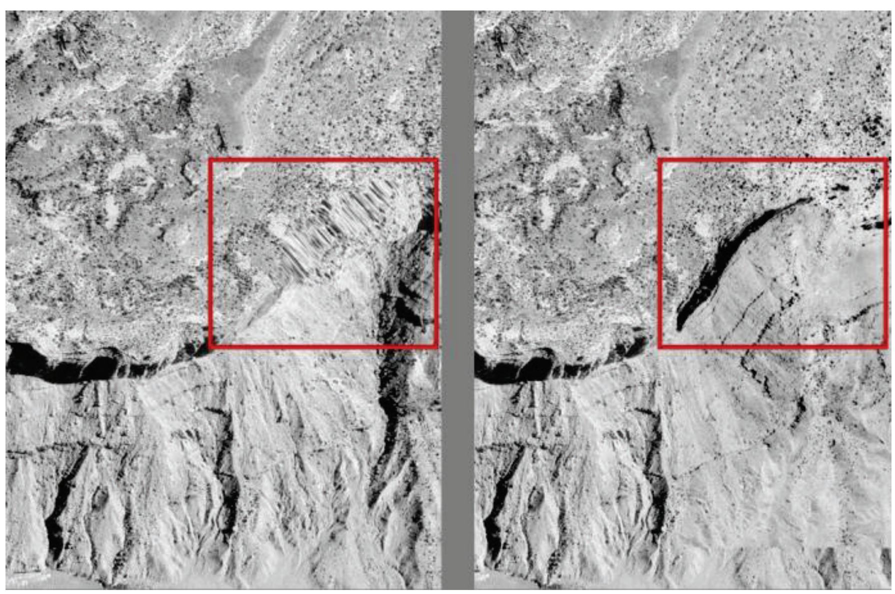
- Each digital orthophoto will initially be created with a certain amount of overlap between adjoining images. This is necessary for determination of brightness differences between images.
- Pixel groups in adjacent images will be compared to determine the final output values along the seam line.
- Images will be processed so tonal values are consistent across boundaries, with no evidence of a seam.
- All radiometric correction will result in minimally measurable, and visually undetectable radiometric seams within or between flight lines, stereo models, or tiles.
- Sanborn calculates the position of the sun in relation to the camera at the time of exposure. This allows correction for hot spots and reflectance in the photography.
- Radiometric adjustment includes color balancing, overall tone adjustment, and brightness and contrast enhancement of the imagery over the entire project. Client-approved sample data (pilot data set) will be used as reference. There will be no null pixels within tiles.

Radial Distortion (Building Lean) Minimization

Radial distortion of above-ground features is a common issue with orthoimagery. Sanborn creates orthophotos using only a relatively small inner area, or so-called "sweet spot," from each available image. This minimizes radial displacement and related problems, which increase toward the outer perimeter of a photograph. Using the "sweet spot" also increases the quality of the color balancing between photos. The high-overlap imagery acquired over major urban areas, as well as the higher acquisition altitude capability offered by the UltraCam Eagle sensor will also contribute significantly to the minimization of building lean and other radial distortion.

Smear Correction Due to Terrain

Sanborn utilizes both the "sweet spot" and intelligent seaming to automatically correct for image smears. Image smears typically are found in areas of high relief where the image angle is parallel to the terrain. An accurate digital elevation model is required to correct this problem. As a result of Sanborn's methodology, clients are guaranteed that valleys within high relief areas remain visible. The following image provides an example of image smearing and its correction:



Smeared terrain *Smeared terrain correction*

Correction of Bridges and Other Elevated Highway Features

Distortion of bridges and other elevated highway features occurs when a DTM models the terrain surface, but not elevated features such as bridges crossing over that DTM. Sanborn corrects bridges and elevated highways as a routine step in our orthophoto creation workflow. Sanborn produces a separate DTM for each elevated highway feature, and when used in Sanborn's rectification process software, elevated highway feature displacements will be corrected, with each feature being restored to its true location. Sanborn will deliver a separate bridge DTM file containing all affected bridges and flyovers.

Before

After

Generation of Final Deliverables

A seamless database of orthorectified imagery will be created and final deliverable tiles "cookie-cut" out of it. This results in deliverable digital orthophoto files that match at a neat line with no overlap or gap. The tiles will be cut to conform to the COAGA 2019's tile scheme, and written out in compliance with COAGA 2019's PLSS desired naming convention. All tiles will be geo-referenced and projected in the specified project coordinate system. A tile index will be provided in Esri Geodatabase format.

All imagery will be delivered at a spatial resolution of 3-, 6-, or 12-inches, in .TIFF/.TIFW format, .   A project-wide MrSID .SID/.SDW format will also be delivered. Options are provided for additional SID/.SDW for each County or city participant. The database will be delivered on USB External Hard Drives.

Digital Orthophoto Quality Assurance

The process involved in producing high quality digital orthophotography is dependent upon the successful execution of many tasks performed by several Sanborn departments. While QA/QC is integrated into the workflow, every orthoimage tiles undergoes a thorough visual inspection by experienced imagery technicians following the conclusion of the production process. Any blemishes or artifacts in the imagery will be corrected prior to submittal. Inspections that will be performed on the orthoimagery include, but are not limited to:

- Visual inspection of geometry—Evaluate final geometric fit for compliance to specifications and/or published data quality statistics:
  - Obvious seams
  - Edge matching (roads, buildings)
  - Bridge warping
  - Excessive radial displacement in buildings
- Visual QC of mosaic—Evaluate product quality and modify as needed to meet project specifications:
  - Blurred imagery
  - Inconsistencies of color balancing

- Artifacts removed
- Shadow detail

- Product packaging—Final review of product with regard to content, format, labeling

Sanborn understands that imagery which does not meet quality and accuracy requirements will be rejected and will need to be re-submitted following corrective measures.

Quality Assurance/Control Checklist

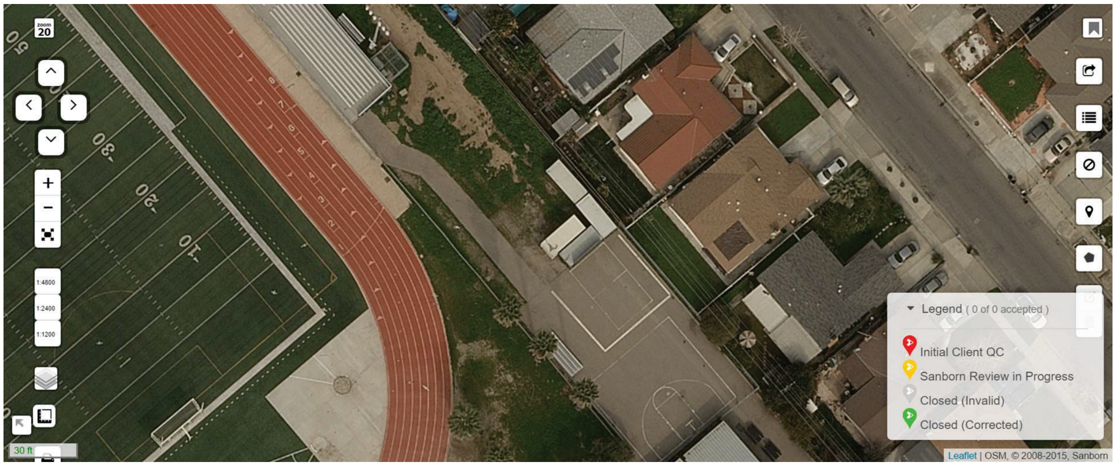
Sanborn uses an independent internal quality review process for all data to ensure adherence to product specifications, data formats and data completeness for all the deliverables across all phases of the contract. Sanborn spends considerable effort to ensure data quality. All data are post-processed in a controlled environment based on strict procedures, not only designed to maintain data integrity, but also to provide the best possible products to COAGA 2019. As a result, we use highly controlled procedures for planning, data acquisition, post-processing, ortho-production, product generation and data delivery. The following table is an outline of the Sanborn Quality procedures across all phases of the project.

QC Checklist		Methodology	Contract Requirements	Lead Sign-off
PRE-ACQUISITION REVIEW: These checks are to make sure flight-planning is done according to the contractual requirements.	Project Boundaries	Confirmed with the Client by the Project Manager and released to the Acquisition Team after sign-off		
	Flight Plan	Checked by Acquisition Manager and submitted to client for review		
	Sensor Settings	Checked and verified by the Acquisition Manager		
	Weather conditions	Verified by the Operator		
	Survey Plan	Checked and verified by the Geomatics Engineer		
FIELD DATA REVIEW: These are the preliminary QC steps done by the Operator & Pilot	Flying Height Checks	Double check the flying height		
	Flight Logs	Flag the flight-lines with cloud coverage and turbulence		
	Sun Angle	Cross reference the sun-angle charts with the flight time		
	Coverage & Overlaps	The data is checked for side and forward overlap and any coverage issues		
POST ACQUISITION DATA REVIEW: These checks are to make sure that the collected data meets the contractual requirements.	Resolution	The resolution of the data is confirmed by the Lead		
	Image Quality	Image free of clouds, haze, over-exposure, saturation, artifacts		
	Data Voids	To ensure the coverage		
	Sun Angle	The data meets the sun-angle requirements		
	Overlaps	The data is checked for side and forward overlap		
DATA CALIBRATION REVIEW: These checks	Initial Orientation Review	The initial orientation is checked for accuracy and completeness		

QC Checklist		Methodology	Contract Requirements	Lead Sign-off
are to ensure that the data meets the contractual accuracy requirements.	Control Network Review	To ensure that the control network residuals are within the error budget		
	AT Accuracy Review	RMSE of the residuals on tie-points and control points		
DTM SURFACE REVIEW: These checks are to ensure that the DTM data going into the orthorectification process is up-to date	Review of the Existing DTM	By surface subtraction between the old and new DTM		
	Update of the DTM	The DTM is updated in the areas of change		
	Horizontal & Vertical Accuracy	Check the horizontal & vertical registration between the DTM and the AT		
ORTHO PRODUCTION REVIEW: These checks are performed during the ortho-production processes	Seamline Editing	All seam-lines are QC'ed and modified accordingly		
	Smearing	The orthos are checked thoroughly for feature smearing		
	Color Balancing	The Orthos are QC'ed and corrected for any color balancing discrepancies		
	Ortho Accuracy	The ortho accuracy is checked by measuring the control and check points on the orthos		
DELIVERY COMPLETENESS & FORMATTING REVIEW: These checks are to ensure that all the products listed in the contract are delivered, they are in the right formats and they completely cover the project area	Delivery Layout	Confirmed by the Client and signed off by Department Lead		
	Imagery Format	Confirmed by the Lead		
	Horizontal Datum	Confirmed by the Lead		
	Vertical Datum	Confirmed by the Lead		
	Unity	Confirmed by the Lead		
	Coverage Check of Deliverables	Visual checks done for each product type by Lead		
	Automated Header Checks	To ensure that all products are generated for delivery in the right formats (including reports)		
	Metadata	Checked by the Lead		

GeoServe Online Client QC Tool

Sanborn provides an optional no-cost service for web-based quality checking of orthoimagery available to the COAGA 2019. Data is served from a central data server at Sanborn to the customer-side computer, and uses a mapping interface from within a standard web browser.



Sanborn's GeoServe online quality control (QC) tool accelerates the review process and expedites final product acceptance. This web-enabled tool removes the need for the physical transport of initial data to the customer site and allows for data to be reviewed and flagged for correction remotely, which reduces the project timeline. Edit flags are stored in a centralized location where they are immediately available for review by others in the organization.

Customer-level login security has been implemented in conjunction with strict firewall functions and policies to help keep unauthorized users from accessing restricted data. Users are able to view available data and add digital issue points to areas which may have perceived problems or errors. These points are submitted directly to a secure centralized database where they are immediately available for others to review. Benefits of the online QC process include:

- Helps reduce the time needed for review as data can be corrected incrementally with edit calls, often speeding the review schedule.
- Provides ease and standard documentation for data quality review needed for contract monitoring and compliance.
- Facilitates coordination between many data reviewers, even when geographically separated.

GeoServe can also consume any vector layers and/or WM(T)S feeds for overlay with the imagery under QC. These can include parcels, streets, city limits, orthos, utilities, zoning, land-use, etc. Sanborn can host these layers on our load-balanced back-end servers for high availability, or directly use them from a third-party service.

Sanborn also offers a WMS/WMTS service option where the orthoimagery tiles are cached as pyramids and served over the web from Sanborn servers. These can then be imported into any OGC-compliant GIS software and used in production workflows. Alternately, point/polygon shapefiles can be created to identify potential issues (the issue details are mentioned in the attribute table of the shapefiles). Sanborn can then review these shapefiles and resolve the issues in an expedited manner.

Option: Planimetric Mapping

Sanborn will perform a manual, 3-Dimensional comprehensive review of the planimetric data, performed by an experienced stereo-compiler using high accuracy stereo-compilation machines.

The option for updated planimetric data layers is provided for Edmond and Norman. All newly acquired planimetric data will meet or exceed ASPRS Class 1 specification; the existing data will meet the original compiled specification. Sanborn will capture all feature layers as detailed in the RFP Appendices, for each participant, in full conformance with the database design provided by the Cities of Edmond and Norman. Sanborn will ensure that existing ground control is evaluated and/or new ground control points are surveyed, to ensure the data meets the required ASPRS Class 1 accuracy specification for the relative 1"=50' (3-inch pixel resolution) and 1" =100' (6-inch pixel resolution) areas.

Sanborn has extensive experience extracting planimetric data from aerial imagery for use in creating or updating GIS data layers using photogrammetric techniques. Sanborn will capture all feature layers as detailed in the RFP, depending on which are desired by each participant, in full conformance with the database designs provided. Sanborn is familiar with both the City of Norman and City of Edmond Geodatabase designs.

Feature Compilation

Sanborn will extract the desired planimetric features from the controlled aerial imagery in a 3D stereoscopic environment, utilizing first-order softcopy workstations operated by photogrammetrists experienced in photo interpretation to update or create the planimetric database, as appropriate to each feature class. The use of softcopy workstations utilizing stereo superimposition technology (planimetric features traced in vector form directly over the top of stereoscopic imagery displayed on the computer monitor) ensures accurate and complete collection of all mapped features. This approach not only provides an accurate horizontal position for the planimetric features, it also provides accurate elevation data where needed, as Sanborn collects a variety of planimetric features such a road edges, retaining walls, and hydrographic features in 3D.

COAGA 2019 should note that there are limitations that impact our ability to fully and accurately capture some planimetric features, including:

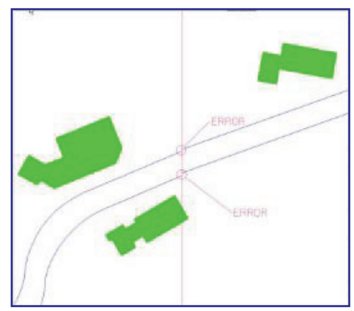
- The scale/limits of resolution of the imagery
- Shadows
- Vegetation cover
- Roof overhangs
- Temporary structures such as mobile canopies
- Vehicles driving or parked over features
- Paved-over or dirt-covered features, or features that are very close in color to paved surfaces or dirt.

The database structure for the project will be uploaded to each softcopy workstation. Quality assurance steps will be in place during the data capture process to ensure that each required planimetric feature is collected to correct graphical representation and attribute requirements outlined in the data dictionary.

At the completion of the stereoscopic compilation tasks, the compiled model is reviewed using softcopy stereo-display to ensure that all data was compiled correctly. A senior photogrammetrist performs this review, with the specific responsibility of maintaining quality control of the project. The compiled file is superimposed over the source imagery, and the required planimetric features in areas of change are reviewed. If features are determined to be missing, or not properly merged into unchanged portions of the database, the location is marked in the file in a separate layer and a QC note is inserted with specific comments. The model will be recalled by the stereo compiler and any necessary corrections addressed. This procedure provides two-way communication, ensuring consistency of data collection in terms of content and interpretation. Once the data are complete and correct, the interactive graphic editing phase begins.

Interactive Graphic Editing and Topological Structuring of Data

Graphic editing procedures involve a combination of interactive and programmatic checks to ensure that the data is cartographically correct and aesthetically pleasing, connectivity of linework is complete, and topology requirements have been met. A variety of intermediate topology checks are performed prior to the building of polygons from line data to ensure that all features defined as being topologically structured have no snapping errors (overshoots/undershoots/slivers). Polygon geometry is created, attributes of all features are populated, and edge-match checking between production blocks is performed.



Edge Matching

Checking for production block edge mismatches is a standard part of all Sanborn projects for clients that tile their data. Using an automated process, each production block is checked against its neighboring production block to ensure that all linework matches exactly. This ensures that attributes of the linework and/or polygon data are also checked. At the conclusion of the process, the graphic technician digitally reviews each production block and corrects any mismatches in line placement or attribution that were flagged by the edge match process. This process is repeated until no errors are returned. Sanborn will ensure that planimetric features will meet all topology requirements when the data is migrated into the target environment, and make the transition to the GIS as efficient as possible.

Layers, Colors, Symbols, Linestyles, and Annotation

Sanborn will format all data layers as detailed in the data dictionary. All symbols, colors, linestyles, and annotation will follow Norman's and Edmond's desired conventions.

Sanborn's listing of data standards and criteria is summarized in the following table.

Data Standards and Criteria	
Edge matching	All data that crosses the edge of a production block will be edge-matched and coordinate connectivity verified.
Point Duplication	No duplicate structures or graphic entities will be allowed. No points will be duplicated within a data string. Points will not be duplicated across production block boundaries unless it corresponds to a delivery area.
Connectivity	Software checkable digitizing errors such as overshoots and undershoots will be eliminated as specified. Lines that intersect will join precisely.

Data Standards and Criteria	
Line Quality	All straight lines will contain only two points: beginning and end. A high graphic appearance shall be achieved. Transitions from straight line to arcs shall be smooth.
Segmentation	Linear elements will not be broken unless the break reflects a visual or attribute code characteristic.
Precision	All data capture will be accomplished in double precision.
Spatial Continuity	All delivered files will represent the specified data as spatially continuous.
Graphic Standards	All graphics will be consistent with accepted symbology and a high cartographic appearance shall be achieved.
Topology	Topology requirements will be defined based upon the COAGA 2019's need. At minimum, illogical overlaps between features and/or feature classes will be avoided.

Translation into Esri and AutoCAD Formats

Once the planimetric and DEM data are completely structured and edited, they are ready to be translated from MicroStation .dgn to Esri Geodatabase. Once the City has accepted the data it will be converted to AutoCAD .DWG formats for delivery. Sanborn has a suite of proprietary translator software that enables the translation to various target systems, including the Esri and AutoCAD environments.

As a final check on the deliverable data, and with the Norman/Edmond database designs as the foundation, Sanborn uses custom software modules to perform QA/QC checks:

- Features and associated attributes are validated for data integrity
- Edge matching processes are run between production blocks
- Data will be verified with the source data and documents for content (missing data) errors, annotation integrity, and aesthetics
- QA/QC reports are generated and checked for errors; they may include:
  - Ensure that all datasets have valid feature attribute tables (FATs)
  - Ensure that all datasets have valid projection and coordinate system definition and properties
  - Verify AOI coverage has been met
  - Verify data edgematching across production blocks
  - Validate topology

Sanborn also has the capability of compiling directly into an Esri Geodatabase from the 3D stereoscopic environment using DAT/EM CAPTURE. All of the compilation methods and topology checks are the same as capture into MicroStation without having to translate the data from a .dgn file into a database

Certification of Compliance with Accuracy Standard for Orthoimagery and Planimetric Data

Following completion and passage of all internal and independent quality control checks, Mr. Doug Zehr, Chief Photogrammetrist, and one of Sanborn's ASPRS Certified Photogrammetrists, will certify the product accuracy as meeting the accuracy requirements as set for the project by the COAGA 2019. The detailed project plan prepared by the Project Manager will include comprehensive acceptance criteria, including the information outlined in the RFP, and review of interim products, such as the aerial triangulation results, that align with our rigorous ISO 9001-based internal quality control and quality assurance methods. Sanborn guarantees that rigorous testing to meet and certify to these standards for quality control for the project and deliverables will be performed. Sanborn has provided a comprehensive description of our quality control procedures following each production step in our workflow in the technical approach. The use of ground checkpoints to test the accuracy solution is described in the Analytical Aerotriangulation section.

Summary of Orthoimagery and Optional Planimetric Deliverables

Sanborn will provide a copy of all deliverables as outlined in the table below. All data will be quality controlled and in full compliance with the standards and specifications set forth by the COAGA 2019 in the RFP.

Summary of Deliverables	
Deliverable	**Description**
Ground Control Field Survey Report	Sanborn will submit a comprehensive survey report documenting the survey in PDF format, and a Microsoft Excel file with all of the coordinate data.
Flight Plans	Sanborn will deliver the final flight line map/photo index with photo centers in Esri Geodatabase or shapefile format.
Aerial Triangulation	Sanborn will provide a fully-indexed AT report that will provide a narrative description of all aspects of the AT phase, tabular information for ground control and check point results, and appendices including full AT solution printouts. An Adobe .PDF version of the report and a Microsoft Excel file with the point coordinates will be provided as well.
Digital Orthophotography	Sanborn will provide a copy of all orthoimagery tiles at the desired spatial resolution of 3-inch, 6-inch, or 12-inches in .TIFF/.TIFW. Options for individual county MrSID and/or JPEG files also provided. JPEG2000 files included for Del City and Midwest City.
MrSID Mosaics	MrSID and/or JPEG 2000 mosaic files for the entire COAGA 2019 area at 1-foot. Additional MrSID/JPEG200 files provided as an option for each area
DEM	Sanborn will provide a copy of the updated digital elevation model created for use in orthorectification in Esri Geodatabase format.
Planimetric Data	Sanborn will provide a copy of the planimetric data in Esri Geodatabase and AutoCAD formats.
Tile Index	Sanborn will provide the final tile layout in Esri Geodatabase format.
Metadata	Sanborn will provide FGDC compliant metadata for the project in the format according to the COAGA 2019 requirements .
Project Documentation	Sanborn will provide a copy of all required project documentation including reports regarding aircraft and camera operation, calibration reports, QA/QC reports, and management & administrative documents.
Deliverable Media	Final data will be delivered on USB External Hard Drives. DVD 2.0, 4.7 GB single sided (4.3 GB usable) disks or FTP download is also available for interim deliverables, such as pilot data sets.

Option: Lidar

We understand the mission-critical nature of this project, and the need to ensure that lidar map products are acquired and delivered accurately, on budget, and to your specifications. Our goal is to provide high-quality geospatial mapping products that are required for the specified COAGA 2019 participants to continue their mission in disseminating flood hazard information in an efficient, effective, and easily accessible manner. This technical approach outlines our methods and procedures for collecting airborne GPS/IMU controlled lidar data, performing GPS surveys and setting of check points, lidar point classification, and generation of the derivative data products. We have extensive experience with and are knowledgable in USGS/FEMA/ASPRS specifications for lidar and lidar derivative product development.

We understand that hydro-flattened lidar is an option for Edmond (with updated HE-DEM and 1-foot contours), and Norman (with updated HE-DEM and 1-foot/2-foot contours). All lidar and lidar products will meet or exceed current USGS, FEMA and ASPRS specifications.

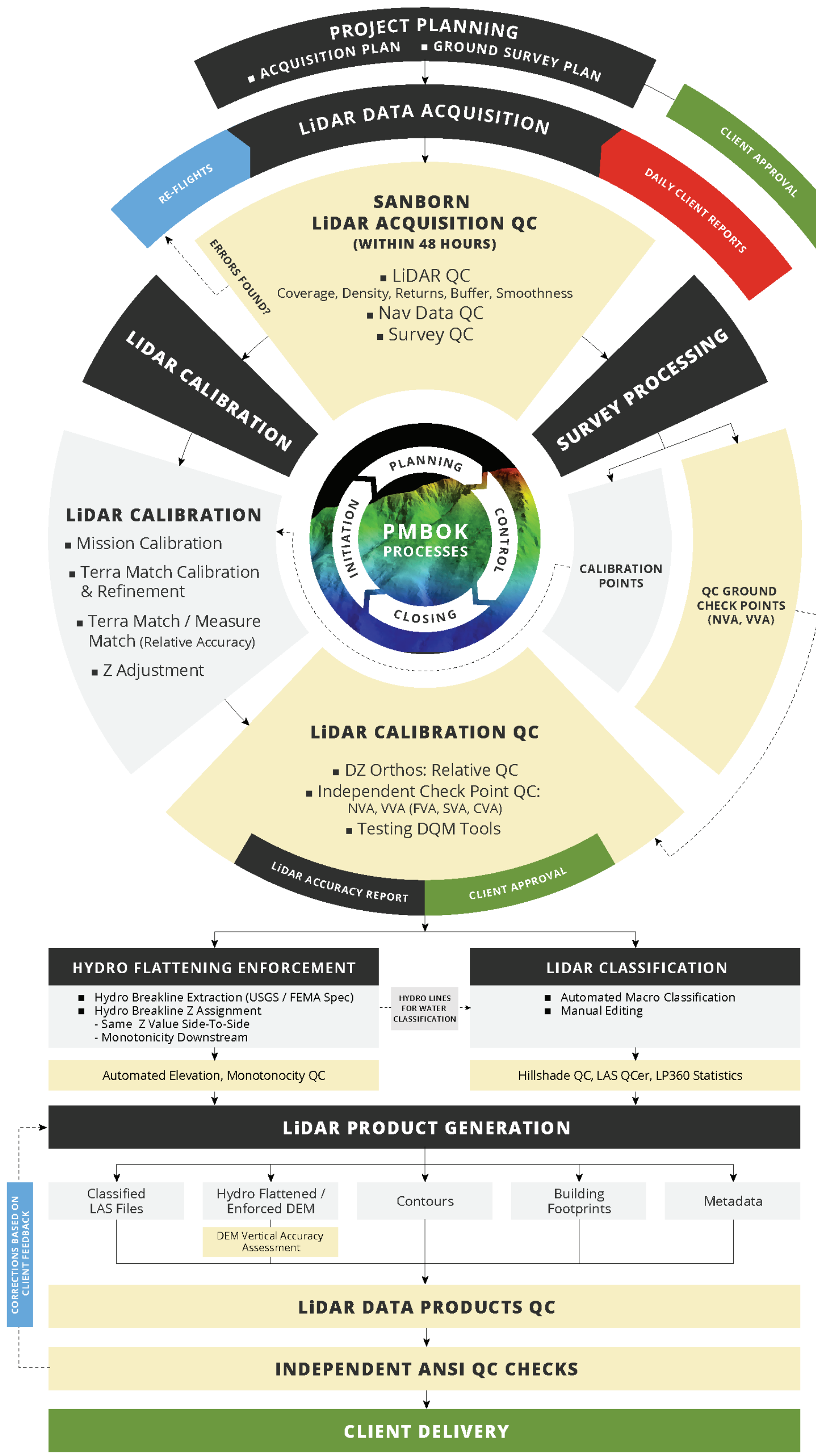
Summary and Overall Workflow

Our overriding goal is to provide high quality, accurate lidar data to COAGA 2019 that meets or exceeds the specifications outlined in the RFP

Sanborn owns, operates and manages the entire process workflow that ensures a successful lidar product delivery to the COAGA 2019. All the data acquisition is accomplished using aircraft and sensors owned by Sanborn and all the end-to-end production workflow steps are managed or performed in Sanborn's Colorado Springs production facility with support provided as necessary by our branch locations or subcontractors.

The major phases of a lidar project lifecycle are illustrated in the flowchart below.

SANBORN LiDAR PROCESS FLOW



The proposed technical description is organized as itemized in the following list:

- Project Planning
  - Acquisition Plan
  - Ground Survey Plans (Calibration Points and Independent validation check-points)
  - Coordination with air traffic control (ATC) and mission execution planning
- Data Acquisition
  - Lidar Acquisition
  - Ground Control Point Survey
  - Field Data QC
- Data Acquisition QC
  - Lidar Quality Validation
  - GPS-IMU/Raw Positioning Quality Validation
  - Survey QC
  - Re-flight Determination/Reflights
- Lidar Calibration
  - Process GPS-IMU
  - Mission calibration
  - Terra Match calibration (relative adjustment)
  - Absolute calibration using calibration points
  - Accuracy Validation using independent check point survey data
- Lidar classification
  - Automated classification using TerraScan macros
  - Manual edit and QC of classification
  - Classification QC using hill-shades
- Hydro-flattening
  - Hydro-breakline collection
  - Elevation assignment to hydro-lines
  - Water classification & Hydro-lines buffer classification
- Lidar Quality Control
- Optional Contour Generation
  - Contour Quality Control
- Deliverables
  - Hydro-breaklines geo-database

Each step within the production process discussed below includes details regarding Sanborn's robust Quality Assurance (QA)/Quality Control (QC) protocols. As a company with ISO-based quality control procedures, Sanborn ensures the products provided to COAGA 2019 will adhere to high quality and accuracy standards. Each production phase is reviewed and accepted before proceeding to the next phase.

Pilot Area

Sanborn will select prototype (pilot) areas for Edmond and Norman, with input from COAGA 2019 and will generate all the products as mentioned in the table above for the pilot area to ensure that there is full conformance of the specification in the pilot delivery. Once the pilot delivery is approved from COAGA 2019, the processing will initiate for the rest of the project area to generate the deliverables for the entire project. Changes requested by the COAGA 2019 subsequent to pilot project, delivery and final approval will be addressed on a case-by-case basis. Once full production has been started, a significant change requested by the COAGA 2019 will impact the project scope and schedule, and could be subject to a formal change order. Problems or errors apparent in the final deliverable will be corrected by Sanborn if they do not conform to previously approved submissions.

Lidar Data Acquisition

Sanborn Lidar Resources

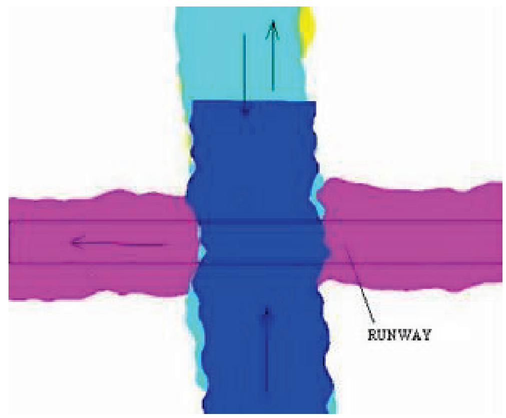
Leica AL70-HP Sensor and Hardware

Sanborn has invested over $5,000,000 in sensors and processing technology to ensure that our lidar capabilities are equal to any in the industry. Sanborn owns two Leica ALS70-HP sensors, which is the primary system we propose to task on the COAGA 2019's projects. Once the project work-order is issued, Sanborn will perform resource analysis to ensure that the adequate numbers of sensors are deployed to the project site(s) to ensure the timely data acquisition (Spring 2019) as per the project requirements. Sanborn has developed sophisticated processes to integrate multiple sensors into our lidar workflow and has standardized our data format to maintain data integrity and accuracies. The specifications of the ALS70-HP sensor are as follows.

Leica ALS-70-HP Lidar Sensor Specifications	
Modes	MPIA / SPIA
Field of View	0 to 72 Degrees
Wavelength	1064 nm (INVISIBLE)
Scan patterns (3 selectable)	Sine, Triangular, Raster
Scan Rate	500 KHz (Effective)
Returns per Pulse	Unlimited
Return Intensity Values	3 per Pulse
Operational Altitude	Up to 3500 Meters
Accuracy, RMSExy	Up to 5 cm
Accuracy, RMSEz	Up to 7 cm
Data Storage Capacity	Up to 6 Hours Mission time
Eye Safety	Operationally eye safe via Leica FlightPro Automatic Eyesafe Shutoff

Installation Calibration

Sanborn conducts extensive calibration and GPS lever arm surveys for all sensors and aircraft installations. The GPS antenna in the aircraft and its reference to the lidar sensor head are surveyed using a Leica total station. Several reference points on the aircraft and sensor are measured to validate the location of the sensor GPS antenna in relation to the sensor head. These reference points include the tail, nose, antenna, sensor reference location, and point below sensor scanner on the ground. This process consistently yields GPS lever arm offsets (x, y, z) locations within two millimeters or less.



Sanborn has established calibration test ranges at the Colorado Springs Airport and downtown Colorado Springs for calibration of the lidar sensors. Every lidar sensor is calibrated after every installation into an aircraft. Recently, Sanborn has instituted an additional calibration dataset for better calibration. Sanborn has surveyed in the downtown calibration with our Lynx Mobile Mapping unit. This system operates two 200 kHz lasers on a mobile platform. This system is capable of achieving two-centimeter accuracy and a lidar point density far more dense than an airborne lidar sensor. This sensor is used to validate and correct for both vertical and horizontal accuracy of the airborne sensors. Results have improved the relative and absolute accuracy of our airborne sensors.

Providing a stable platform of all Sanborn sensors is critical for project success so the removal and installation of sensors from Sanborn aircraft seldom occurs. As a result, Sanborn has instituted a routine calibration schedule of every three months for every lidar sensor.

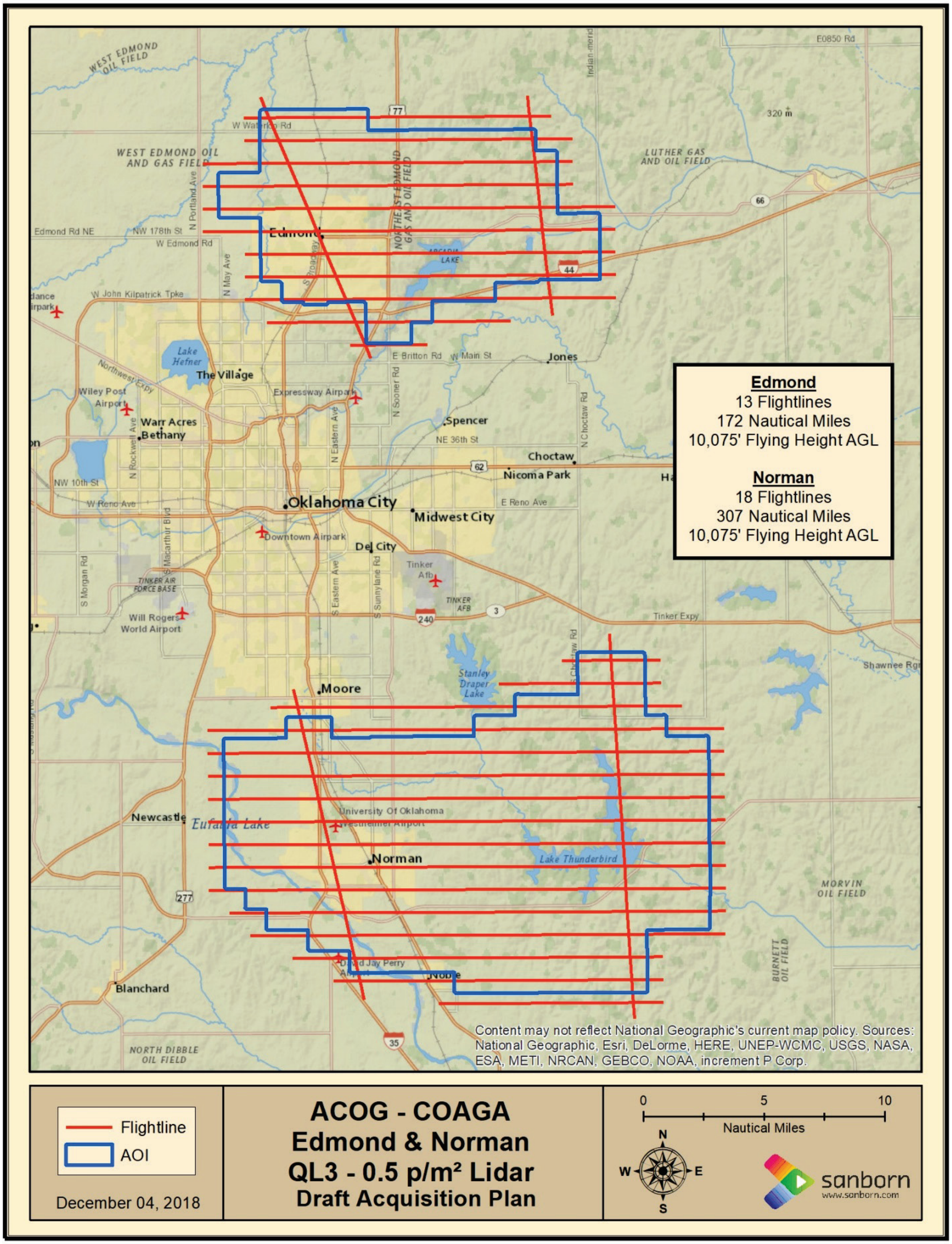
Calibration missions are conducted over a surveyed runway surface and a series of surveyed buildings at three different altitudes: 800 meters, 1,500 meters, and 2,500 meters for the Leica MPia systems. A series of flight lines over the calibration test site are flown in both parallel and perpendicular flight lines at each altitude. In addition, for the Leica MPia system, the system is run in bit mode on the ground to assess the relationship of four returns in Bank A in single pulse mode and the relationship of the four returns in Bank A and Bank B for the multi-pulse mode. The image above represents a calibration run at one altitude and indicates three opposing flight lines perpendicular to the runway and one flight line parallel over the runway. The runway is surveyed using kinematic survey procedures during every calibration. Static GPS validation surveys are conducted to verify the kinematic reference survey.

The goal of the calibration missions is to determine any necessary software adjustments for the hardware to ensure the highest relative and absolute accuracy achievable. Measurements for roll, pitch, yaw, torsion, pitch error slope, Z–Bias, and range correction are checked, calculated, and determined. Other variables like relative accuracy between flight lines, scan factors, and intensity table values are checked and changed if necessary. Given that Sanborn's sensors remain stable once in an aircraft platform, it is often not necessary to change these parameters, but it is imperative to validate them routinely. In addition, several tests are done on the IMU and GPS systems to validate proper operation and accuracy. It is imperative to continuously check these sensors and make necessary changes as required.

Flight Planning

Sanborn has prepared a preliminary **sample** flight plans for Edmond and Norman, based on your requirements and used as a basis for our proposal for these two areas. A final flight plan will be updated once the actual project area is assigned and will be submitted for approval upon project execution.

We propose to mobilize one aircraft/Leica sensor to the area, for completion of the imagery acquisition within ~**2 days**. This provides more than adequate time to complete acquisition in with leaf-off and optimum ground/weather conditions in Spring 2019. Sanborn will closely monitor weather conditions and acquisition status as the window progresses, and will mobilize a 2^{nd} aircraft/sensor if needed.


Edmond
13 Flightlines
172 Nautical Miles
10,075' Flying Height AGL
Norman
18 Flightlines
307 Nautical Miles
10,075' Flying Height AGL
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
Flightline
AOI
December 04, 2018
ACOG - COAGA
Edmond & Norman
QL3 - 0.5 p/m² Lidar
Draft Acquisition Plan
0
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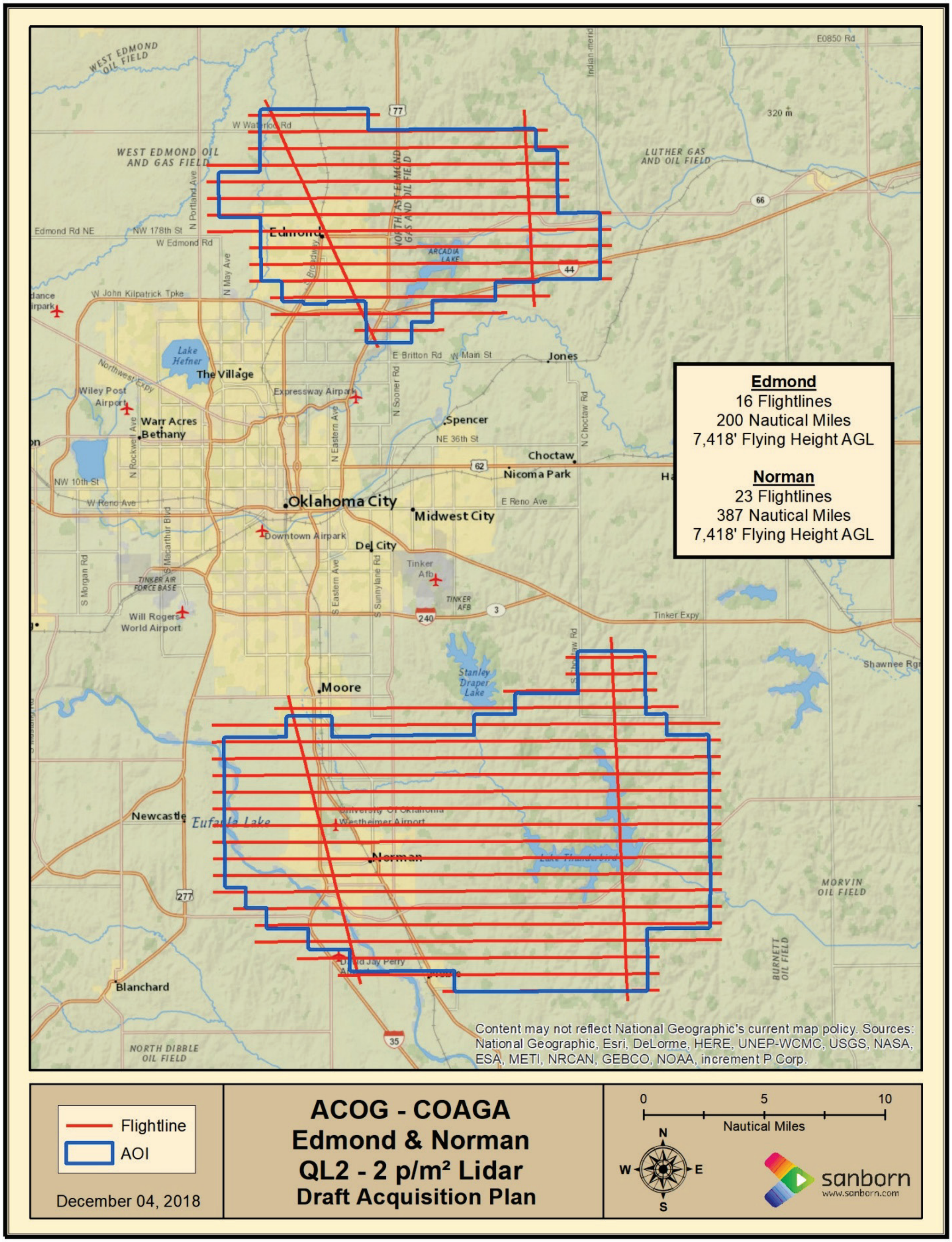
Edmond
16 Flightlines
200 Nautical Miles
7,418' Flying Height AGL
Norman
23 Flightlines
387 Nautical Miles
7,418' Flying Height AGL
Oklahoma City
Edmond
Norman
Moore
Midwest City
Del City
The Village
Warr Acres
Bethany
Spencer
Jones
Choctaw
Nicoma Park
Newcastle
Blanchard
Lake Hefner
Stanley Draper Lake
Downtown Airpark
Expressway Airpark
Wiley Post Airport
Will Rogers World Airport
Tinker Afb
WEST EDMOND OIL AND GAS FIELD
LUTHER GAS AND OIL FIELD
MORVIN OIL FIELD
NORTH DIBBLE OIL FIELD
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
Flightline
AOI
December 04, 2018
ACOG - COAGA
Edmond & Norman
QL2 - 2 p/m² Lidar
Draft Acquisition Plan
0
5
10
Nautical Miles
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The tables below show the design parameters for the lidar data acquisition.

Lidar Data Acquisition QL2	
Project Design Parameters	
AOI Coverage (mi²)	406.76
Buffer Distance around AOI	100 m
NPS	0.71 m
Flight line Overlap (%)	20
Sensor Settings	
Scan Angle FOV (degrees)	40
Scan Rate (Hz)	42.5
Pulse Rate (kHz)	242.2
Flight Parameters	
Altitude (m / ft)	2261 / 7418
Air Speed (kts)	130
Total Number of Lines	39
Total Line Miles	586
Total Time On Line (hrs)	4.51
Total Time On Turns (hrs)	2.60
Total Time (Hrs)	7.11

Lidar Data Acquisition QL3	
Project Design Parameters	
AOI Coverage (mi²)	406.76
Buffer Distance around AOI	100 m
NPS	1.41 m
Flight line Overlap (%)	20
Sensor Settings	
Scan Angle FOV (degrees)	40
Scan Rate (Hz)	22.2
Pulse Rate (kHz)	89.6
Flight Parameters	
Altitude (m / ft)	3071 / 10075
Air Speed (kts)	130
Total Number of Lines	31
Total Line Miles	479
Total Time On Line (hrs)	3.68
Total Time On Turns (hrs)	2.07
Total Time (Hrs)	5.75

Sanborn has extensive experience flying throughout the United States. Using our historic knowledge, Sanborn has determined the operational parameters for successful acquisition. Here are the key operational best practices that Sanborn employs to ensure the quality of the lidar data collection in the field:

- Calibration lines: For each lidar mission,
  - 1 parallel and 1 perpendicular to the run-way at the beginning of the flight
  - 2 parallel to the run-way at the end of the flight

- 2 cross flights are planned at the each edge of the block.
- Cross-flights are planned to connect adjacent flight blocks.
- The quality of the GPS-IMU solution is key for lidar. In order to make sure that we are getting the best quality of GPS-IMU solution, here are the key operational considerations:
  - The base-line distance should be less than 25 miles
  - Setting up 2 base-stations is mandatory (1 at the airport + 1 at the project area)
  - Only the CORS stations with 1 hertz frequency are considered to be usable for GPS-IMU processing
  - Kp index less than 4
  - PDoP <3.2: Minimum satellite lock of 6 satellites
  - Airplane banking turn angles <20 degrees for lidar
  - The plane sits static on the tarmac for about 10 minutes before (after the GPS is turned on) and 10 minutes after the collection (before switching off the system)
  - A single flight-line is never planned to be longer than 20 minutes at a stretch. This is to minimize the IMU-drifting affect
- The deviation from the planned flight course should be less than 5 degrees in all three angular degree of freedoms (roll <5 degrees; pitch <5 degrees and heading <5 degrees).
- The plane will to stay on course within 50-70 feet from the planned trajectory (in the horizontal plane).
- All the arrangements and timing coordination for restricted airspaces are made before mobilizing to the project site.
- Our teams monitor atmospheric and safety considerations, including relative humidity, clouds and haze conditions. If smoke exists in the collection area, missions will not be flown.
- If optimal conditions exist at night, operations can be conducted then as well. We will not collect data in moderate to severe turbulence, or with a cross wind of 25 knots or more.

Acquisition Tracking, Reporting and Quality Control

Sanborn employs rigorous QC processes within 48-72 hours of data collection to ensure that the data acquired meets the requirements of the project. The acquisition and QC status is updated on a daily basis, and the information will be accessible to COAGA 2019 via a GIS-based Web page.

- *Field data verification:* The field crew downloads the data, and ships a duplicate set of the data on portable hard drives via next-day courier delivery to the production office. The field crew then processes the approximate GPS-IMU solution, the decimated flight lines, and views the point cloud to confirm the quality of the data collected. This is accomplished within 24 hours of data collection. Special attention is paid to flight lines where any turbulence/disturbance or sensor-related problems are marked on the flight logs. The flight plan for the next day is updated on the basis of the lines flagged by the acquisition team during the field data verification process.
- *Office data verification*: The data for each mission arrives in the production office on the day after acquisition. The lidar processing team processes the data with precise GPS-IMU solutions and generates the full resolution LAS flight line strips. The team then checks the data carefully for gaps, sensor anomalies, NPS, FOV, side-lap, and other flight-related parameters. Any re-flights needs identified during this QC process are then transmitted back

to the acquisition team by the acquisition manager. The office data verification is completed within 24 hours of receiving the LIDAR data in the office.

- *Online flight tracking system:* Sanborn has designed a GIS-based online acquisition system that can be used by the client to track the status of acquisition, data validation, QC, and re-flights on a daily basis.
- *Reporting to COAGA 2019:* Sanborn's project manager will send an e-mail to COAGA 2019's project manager to indicate whether any lidar acquisition was accomplished during the preceding day. The e-mail will also supply a brief description of the areas captured and/or an explanation for areas where data was not collected.

Lidar Post Processing

All data is post-processed in a controlled environment based upon strict procedures designed to maintain data integrity and to provide the best possible data to COAGA 2019. The following is an outline of the data processing work flow completed at Sanborn's office after the field verification and in-field QA/QC processes have been completed.

- Data Management / Production Management using GeoCue
- Lidar Calibration
- Lidar Classification
- Final Product Generation
- Creation of Metadata
- Quality Control

Lidar Calibration Overview

Sanborn conducts possibly the most extensive sensor calibration in the industry. We calibrate all sensors (1) prior and after installation (2) every three months, and (3) during every mission. This enables Sanborn to guarantee the data accuracies required by our clients. Our calibration process is detailed below.

- Installation Calibration
- GPS-IMU Processing
- Mission Calibration
- Final Lidar Calibration Using TerraMatch
- DZ Ortho process: for relative accuracy
- Check-Point Z Adjustment

Horizontal point accuracy is a function of angular origination of the pulse, IMU orientation, and the scanner encoder and ranging function. These will vary depending on the proposed point density selected for the collection. Statistically, the error is roughly one-third of the illuminated foot print on the ground and is a function of the beam divergences. It is also affected by the reflective nature of the surface at which it strikes.

The biggest factor in vertical accuracy is GPS data quality, but it also can be affected by laser range function, IMU orientation, and scan angle. There is a higher percentage of range ambiguity at higher repetition rates. This is further dependent on the distance between returns. Sanborn accounts for this by adjusting the repetition rate of the laser based on collection parameters and desired point sample densities. In addition, during the processing of the lidar, the flight line swath data is trimmed to cut off excess errors at the FOV edge. Sanborn will ensure that the calibrated lidar dataset meets or exceeds the specifications of the project.

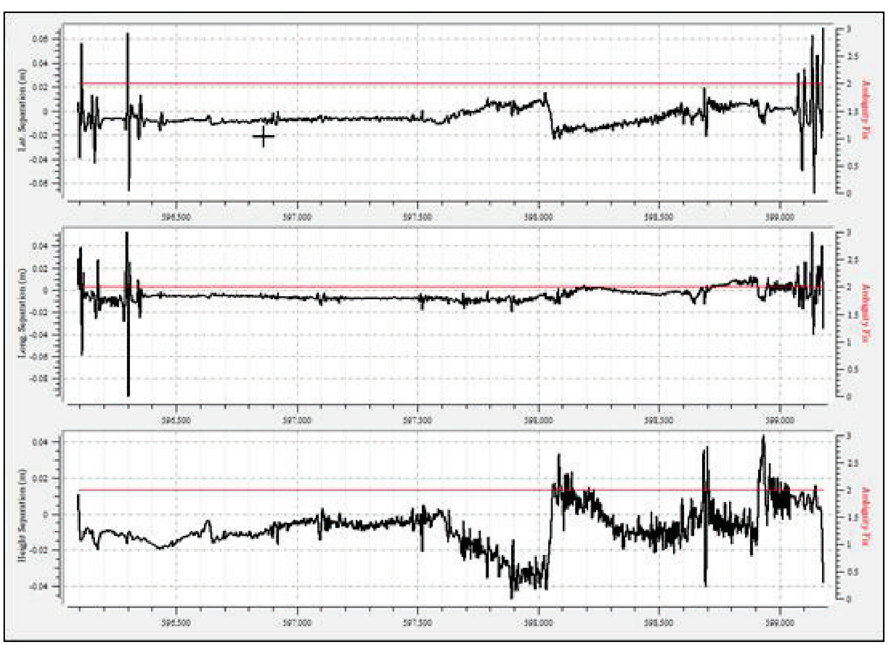
GPS-IMU Processing

The differential kinematic data are processed together with a minimum of two static base stations and the solutions are compared. This procedure verifies the integrity of the base-station coordinates and elevations. Each processing session is computed in both forward and reverse temporal directions. The comparison of these solutions provides insight into the quality of the kinematic ambiguity resolution.

During the mission planning process, Positional Dilution of Precision (PDOP) is considered through vendor planning software packages. Sanborn uses Trimble's Qplan and Ashtech's MPwin GPS planning software. All mission collections will be conducted with a PDOP of 3.2 or lower. The KP index is also considered prior to mission collection. KP index is a measurement of geomagnetic activity at the earth's surface that can greatly affect the GPS solution. Therefore, no collection will occur when the KP index is at or above 4.

Airborne and ground GPS data are collected at half-second epochs for the duration of all missions. In addition, five-minute fixed static surveys are collected at the start and end of all missions. This step insures the airborne GPS unit is functioning properly and the solution is fixed.

There are several considerations to be taken into account during the actual processing of the GPS data. Parameters such as satellite health, cycle-slip tolerance, satellite elevation mask, kinematic ambiguity resolution, ionospheric correction, L1/L2 carrier phase, and base station information will be refined to yield the best possible GPS solution. In addition, several QC/QA checks are done within the software to ensure a best fit solution. The following figure illustrates a suitable combined solution, predominantly within 4cm.



Combined Solution Example

Lidar Mission Calibration

In addition to the process Sanborn conducts at installation and every three months, Sanborn performs an abbreviated version of the installation calibration process for every lidar mission. At every project base of operation, the runway is kinematically surveyed by making three passes down the runway. One pass is down the middle of the runway and two are down the edges of the runway, providing an average of 3000 to 4000 points along the runway. The vertical accuracy will be no less than 3 cm (1 sigma). Elevation points will be sufficiently dense to adequately represent the surface to the required accuracy. The test surface will be approximately 70 meters wide and 500 meters long.

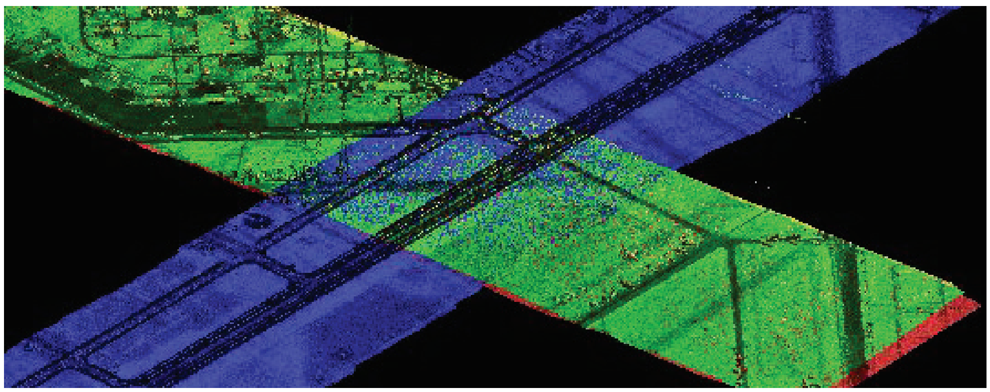
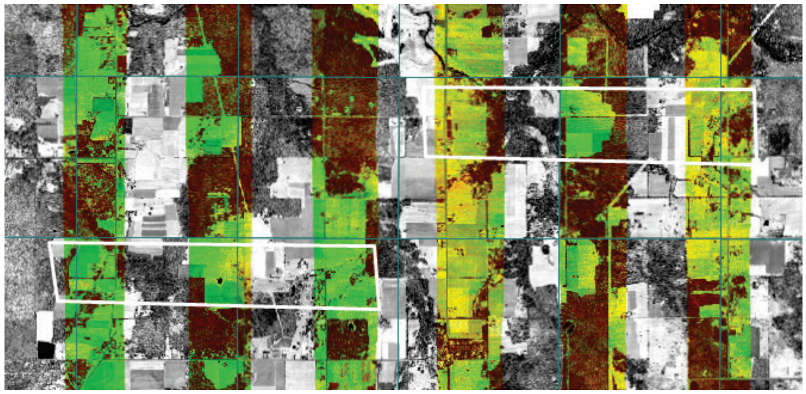


Illustration of four different calibration strips on a runway. TerraMatch finds and corrects errors automatically, creating an initially accurate dataset.

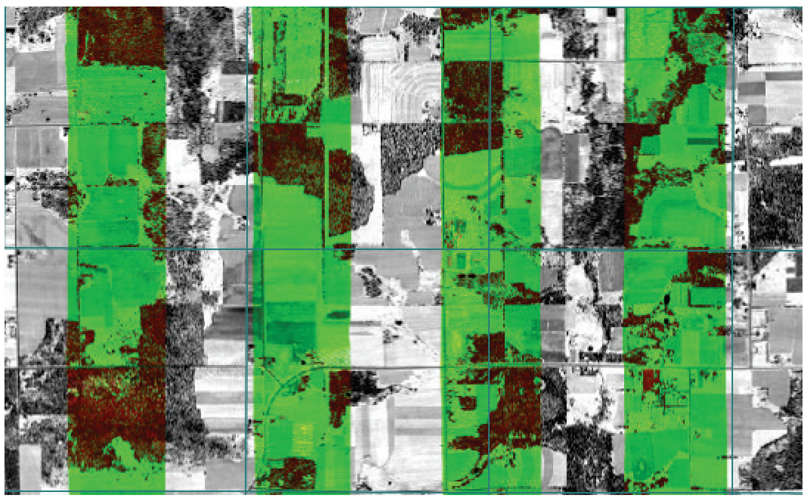
Prior to project area collection, two passes perpendicular to the runway in opposing directions are flown. At the end of every mission collection, two additional passes over the runway are flown. One pass is parallel to the runway to detect edge of scan differences in relationship to the runway and other calibration lines. The final line is flown perpendicular to the runway to check the swath repeatability from the beginning to the end of the flight. In addition, a cross flight is flown in all project areas to check flight line repeatability within the project area. The mission calibration is done to verify all the parameters mentioned in the installation calibration section and the graphic in that section is representative of the mission calibration. In addition, the system is run in bit mode for every mission to further valid and adjust the relative relationship of the return as they relate to single pulse or multi-pulse, and Bank A and Bank B. This process ensures both relative and absolute accuracy.

Final Lidar Calibration Using TerraMatch

Sanborn uses many different calibration techniques to ensure the client is getting the most accurate data possible. By implementing the use of TerraMatch, a product from TerraSolid, the dataset can be corrected for systematic biases. These adjustments are almost completely automated, and assist in the accuracy against the surveyed control points. TerraMatch further improves roll, pitch, heading, and torsion between each mission to form a dataset that is precise, and well within the client-defined accuracy specifications. By placing sample tiles perpendicular to the direction of flight, TerraMatch analyzes each swath simultaneously. A file is then output containing each swath's corrections. This correction file is then applied to the entire project and/or block.



Swath to swath systematic errors are shown. TerraMatch uses the sample tiles to find biases between swaths and correct for them.



Swath to swath errors are corrected automatically by applying correction file.

Dz Ortho Imagery Process

Sanborn uses Dz Ortho images to analyze the calibration. These images are specific to lidar processing, and quickly show any potential calibration issues. Dz Orthos are recreated between the initial runway calibration and again after the TerraMatch step. The coloring of the images indicates degree of offsets between each swath in four intervals, ranging from green to red. Image settings are as follows.

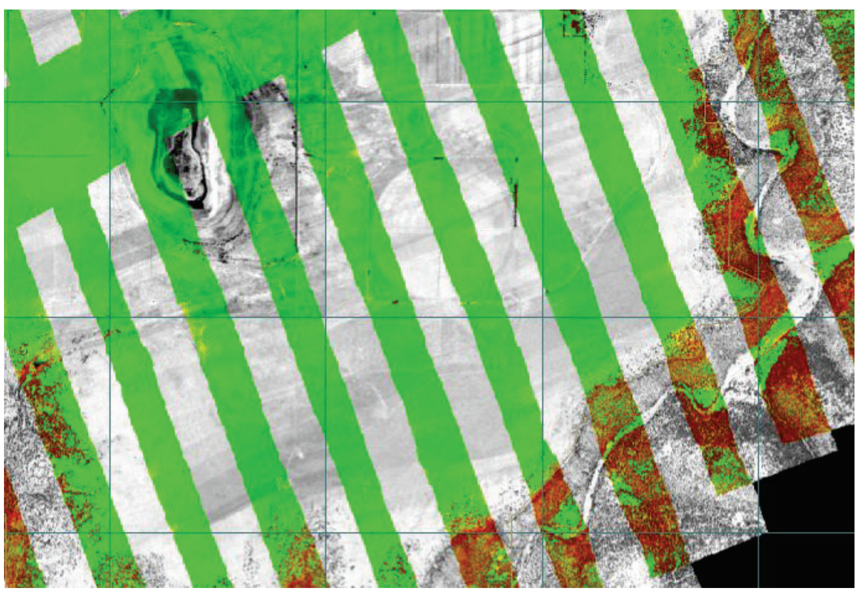
- Green: 0-7cm offset
- Yellow: 7.1-14cm offset
- Orange: 14.1-21cm offset
- Red: >21.1cm offset

These images are efficient and easily viewed, and the lidar team at Sanborn manually analyzes the actual data to ensure data quality. Bare earth should always show as green from swath to swath. Vegetation is usually shown as orange or red. After all TerraMatch corrections are applied, the dataset is filtered and manually edited for anomalies to provide a clean, artifact-free bare earth dataset.

Control Point Z Adjustment

Sanborn collects multiple survey control points for each project area to accurately calibrate the lidar data. Internally, we call these control points lidar Calibration Points as these points are used in the lidar calibration process and are independent of the Check points (non-vegetated vertical accuracy [NVA] and vegetated vertical accuracy [VVA]) used to report the accuracy of the lidar data as per the USGS and the ASPRS requirements. Typically the calibration points are selected in open flat/gently-sloped ground locations and are well distributed through the lidar calibration blocks. When the project consists of multiple overlapping/bordering calibration blocks, some of the calibration points are selected in the overlapping areas between at the boundary of the blocks so that the consistency and accuracy of the data can be ensured at the transition area between two blocks.

Once the data has been through the TerraMatch calibration process, a Macro classification routine is run on the lidar dataset to classify the bare earth data (only automated classification). The auto-generated bare earth from the lidar data is compared to the processed survey points. In order to achieve the lowest RMSE, the data is adjusted to the Average Dz. This is the mean of all points and their offset to the lidar. Once the lidar is vertically adjusted, it's ready for edit classification and lidar product generation.



This is a final calibrated dataset showing swath to swath edge match coloring. Dz coloring indicates the degree of offsets between each swath.

Lidar Accuracy Testing

To support the accuracy and interpolation of the 1-foot contour areas, Sanborn will acquire and process lidar that meets or exceeds the density and accuracy requirements of USGS Quality Level 2 data (Aggregate Nominal Pulse Density ≥2.0 pls/m²). To support the accuracy and interpolation of the 2-foot contour areas, Sanborn will acquire and process lidar that meets or exceeds the density and accuracy requirements of USGS Quality Level 3 data (Aggregate Nominal Pulse Density ≥0.5 pls/m²).

As per the USGS Lidar Base Specification Version 1.3, the table below shows the accuracy requirements of the QL2 and QL3 lidar data:

Lidar Accuracy Requirements		
Relative Accuracy	**QL2**	**QL3**
Smooth Surface Repeatability (cm)	≤6	≤12
Swath Overlap Difference $RMSD_Z$ (cm)	≤8	≤16
Absolute Accuracy	**QL2**	**QL3**
$RMSE_Z$ NVA (Non-vegetated Vertical Accuracy) (cm)	≤10.0	≤20.0
NVA @ 95% Confidence Level (cm)	≤19.6	≤39.2
VVA @ 95^{th} Percentile (cm)	≤30.0	≤60.0

Sanborn understands the requirement to test the accuracy of the lidar data against field check points as per the latest ASPRS and USGS guidelines. The calibration of the lidar data will be verified by assessing the relative and absolute accuracies of the calibrated point cloud. Sanborn will establish check points, separate from the calibration points, that are not be used in the calibration process. The survey will be completed so that the check points are three times the accuracy of the Vertical Accuracy Class.

Quality assessment against ground check points will be performed in accordance with ASPRS Positional Accuracy Standards for Digital Geospatial Data Version 1.0 (2014). The quantity of check points will be as shown in the table from the ASPRS standards (Page A19; Table C.1). Well-distributed independent check points will be distributed to all of the present land cover classes shown in the table below in accordance with ASPRS guidelines.

We have included the total number of check points for Edmond – 25 (20 NVA + 5 VVA) and Norman – 60 (35 NVA + 25 VVA) for a total of 85 check points (55 NVA + 30 VVA).

Vertical Accuracy Check Points		
	Number of Points	**Land Cover Types**
NVA	55	Located in traditional open terrain (bare soil, sand, rocks, and short grass) and urban terrain (asphalt and concrete surfaces).
VVA	30	Tall weeds and crops, brush lands, and fully forested areas.

Sanborn will perform a statistical analysis; reconciling lidar elevation coordinates with field check point elevations and corresponding coordinate locations. Absolute vertical accuracy of the lidar data and the derived DEM will be assessed and reported in accordance with ASPRS (2014) and provided to COAGA 2019.

Lidar Classification

The first step in the creation of topographic products from lidar (following post processing and calibration) is classification of the point cloud.

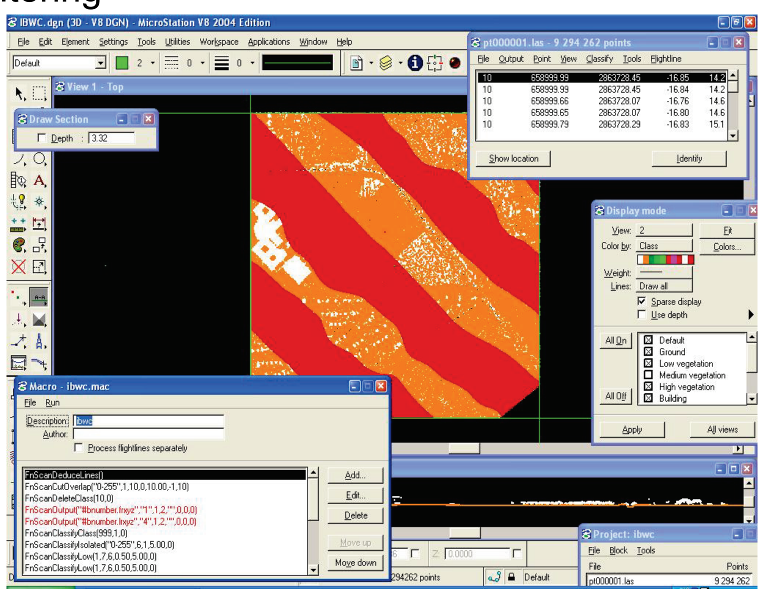
Typical LAS Classification Options	
Code 1	Processed, but unclassified
Code 2	Bare-earth ground
Code 7	Low Noise
Code 9	Water
Code 10	Ignored Ground (Breakline Proximity)
Code 17	Bridge decks
Code 18	High Noise

Sanborn will ensure that the point classification will be consistent across the entire project and there are no noticeable variations in the character, texture, or quality of the classification between tiles, swaths, lifts, or other non-natural divisions existing in the data. Sanborn will make sure that within any 1km x 1km area, not more than 1 percent of the points will possess a demonstrably erroneous classification value.

The point classification is divided into the following steps.

- Automated macro filtering
- Manual QC and editing of the classification
- Final classification QC using the hillshade surfaces

Automated Macro Filtering

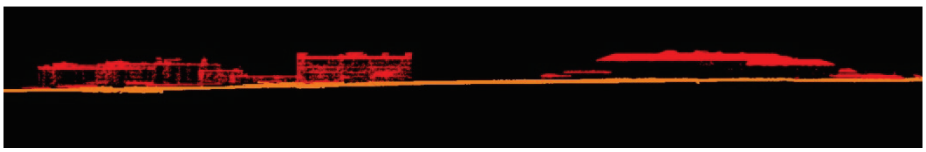


The initial lidar point cloud classification is done using the automated Terra-Scan macros. The macros are designed to classify the points to the classes required for the project. Sanborn uses a variety of commercial and proprietary software to build macros for automated classification. The macros are specific for each type of geography within a project, taking into consideration terrain relief, ground cover, natural, and man-made features. The macros exploit the information related to the number of returns of a pulse, elevation, slope, and height from ground and other terrain characteristics to classify the point cloud in an automated fashion. The routines will classify points based upon the laser attributes including intensity, elevation and the numeric value of the return.

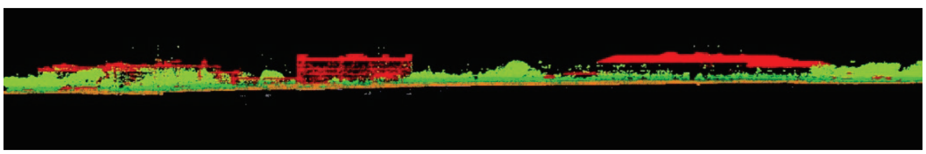
Manual QC and Editing of the Classification

Following the automated classification process, a supervised or manual classification is performed. Sanborn's software can handle an unlimited number of different surfaces in the same digital file. Sanborn's lidar editing team goes through the tiles with great precision to make sure that the points are classified correctly. 3D tools include cross-section or profile views of points to aid in classification and surface model visualization with rapid contour development to spot bare earth blunders for re-classification. Color triangles display of TINs, colored grids for shaded relief, and other sophisticated visualization tools support the manual classification. The KML file of the project area is made available to the editors so that in case of any confusion in feature identification, they can verify the feature in the imagery and classify the points in the right class accordingly.

The following are classification examples produced by Sanborn:



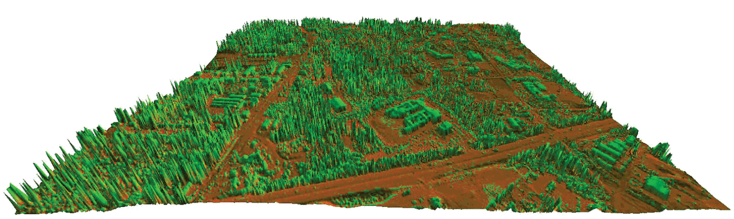
Profile (side) view of bare earth and building structures



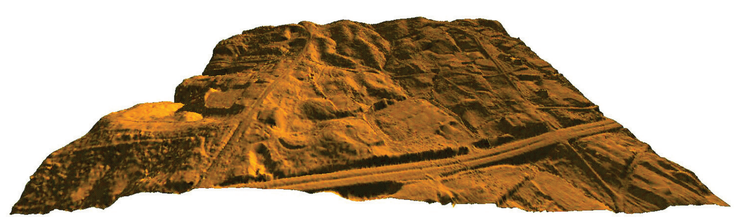
Profile view with vegetation classified from low, medium, to high

Final Classification QC Using the Hillshade Surface

Part of Sanborn's QC process is eliminating need for extensive manual editing, and replacing this with an automated way to quickly depict outliers or anomalies in a bare earth dataset. Through the production of hillshaded surfaces, Sanborn's lidar team can scroll through hillshades (TIF images) generated from the bare earth. This means quicker file load times and the ability to find errors in the bare earth without manually opening each individual lidar tile. The team member can also import these hillshades into Google Earth to provide an even better perspective on the terrain. Hillshades are created automatically and quickly, providing an even more efficient streamline editing process.



Surface with Non-Terrain Artifacts (green)



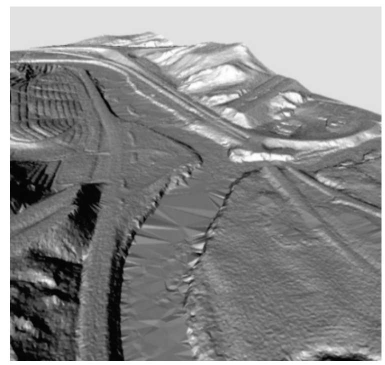
Surface with Classified DTM

Hydro-Flattening and Hydro-Enforcement

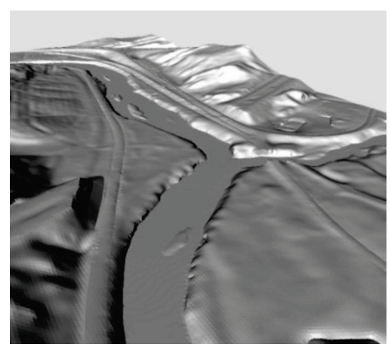
Sanborn has designed custom workflow to produced hydro-flattened and/or hydro-enforced DEMs lidar.

Hydro-flattened describes the specific type of DEM required by the USGS National Geospatial Program (NGP) for integration into the NED. Hydro-flattening is the process of creating a lidar-derived DEM in which water surfaces appear and behave as they would in traditional topographic DEMs created from photogrammetric digital terrain models (DTMs). A traditional topographic DEM such as the NED represents the actual ground surface, and hydrologic features are handled in established ways. Roadways crossing drainages passing through culverts remain in the surface model because they are part of the landscape, as the culvert beneath the road is the manmade feature. Bridges and other manmade structures above the landscape are removed.

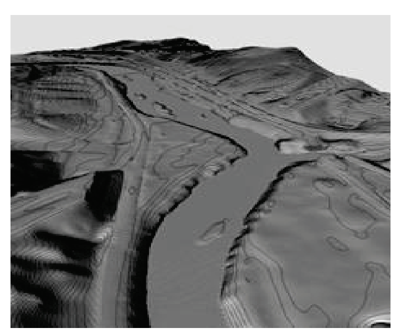
Hydro-enforcement is an important and useful modification of the traditional topographic DEM (hydro-flattened DEM) and produces hydrologic surfaces that are fundamentally different at a functional level. Hydrologic surfaces are identical to topographic surfaces in many respects but they differ significantly in specific ways. In a topographic DEM, roadways over culverts are included in the surface as part of the landscape. From a hydrologic perspective however, these roadways create artificial impediments (digital dams) to the drainages and introduce sinks (un-drained areas) into the landscape.



Lidar surface before breaklines



Lidar surface after breakline enforcement and hydroflattening



Lidar DTM surface showing smoothed contours

Sanborn digitizes hydrology features and edge-of-water breaklines using stereo-intensity images into a 3D dataset. Planimetric mapping includes all hydrology and select man-made features, such as bridges and dams that affect hydrological flow. During this phase, each tile is viewed in both 2D and 3D perspectives as intensity images, shaded relief maps and/or digital surface models (DSM). Sanborn populates the "Z" value for the points, lines, and polygons referencing the bare-earth lidar. Each hydrology feature is digitized in true horizontal position, and the Feature Type and Class are captured along with the X, Y, and Z attributes. Once all of the features have been captured, a second technician performs a review for content and accuracy referencing the collected features to the base lidar data and reference imagery before releasing the tile for final edit.

Sanborn will ensure the DTM is hydrologically enhanced to ensure a high level of detail with regards to the breaklines for the generation of 1-foot or 2-foot contours and spot elevations at traditional locations. The drainage enforced breaklines with ensure that the contours will meet a vertical accuracy of one-half of the contour level.

Sanborn will provide breaklines at the following locations listed below, in order to ensure a hydrologically enforced 1-

foot or 2-foot contour dataset.

- Inland ponds and lakes
  - Flattened water bodies are represented as flat and level water surface (a single elevation for every bank vertex defining the water body's perimeter).
  - The entire water-surface edge is at or below the immediately surrounding terrain
  - Long impoundments, such as reservoirs, inlets, and fjords, whose water-surface elevations decrease with downstream travel, are compiled as streams or rivers.
- Inland streams and rivers
  - Flattened streams and rivers are represented as a flat and level water surface from bank to bank, perpendicular to the apparent flow centerline.
  - Flattened streams and rivers are represented as a gradient downhill water surface, following the immediately surrounding terrain.
  - In cases of sharp turns of rapidly moving water, where the natural water surface is notably not level bank-to-bank, the water surface is represented as it exists while maintaining an aesthetic cartographic appearance.
  - The entire water surface edges are at or below the immediately surrounding terrain.
  - Stream channels shall break at culvert locations, leaving the roadway over the culvert intact.
  - Bridges in all their forms are removed from the DEM.
  - Streams are continuous at bridge locations.
  - When the identification of a structure as a bridge or culvert cannot be made definitively, the feature is regarded as a culvert.
- Non-tidal boundary waters
  - Boundary waters are represented only as an edge or edges within the project. Collection does not include the opposite shore.
  - The entire water surface edges are at or below the immediately surrounding terrain.
  - The water surface elevation will be consistent throughout the project.
  - The water surfaces are flat and level, or as appropriate for the type of water body (level for lakes, a gradient for streams and rivers).
  - Any unusual changes in the water surface elevation during the course of the collection (such as increased upstream dam discharge) are documented in the project metadata.
- Islands
  - Permanent islands shall be delineated in all water bodies.

Sanborn's final processing includes the use of custom routines to validate flow direction and monotonicity to ensure all vector nodes are flowing downhill for single- and double-line streams, or are the same elevation for pools of water, including lakes and ponds. Other processing may include using standard Esri tools to eliminate pseudo-nodes that would impair hydrologic analysis. These added-value processing techniques provide a gateway for the datasets to be used for redefining and providing better resolution and accuracy for watershed, lake shed, and boundaries definition.

Lidar Quality Control

Sanborn uses a quality-review process for all data to ensure adherence to product specifications, data formats, and data completeness for all deliverables. All data is post-processed in a controlled environment based on strict quality procedures designed to maintain data integrity through highly standardized and controlled procedures for data acquisition, post-processing, and validation. The following table provides an outline of Sanborn quality assurance and control procedures for a lidar project.

QC Checklist		Methodology	Contractual Requirements	Department Lead Sign-off
PRE-ACQUISITION REVIEW: These checks are to make sure flight planning is done according to the contractual requirements.	Project boundaries	Confirmed with the client by the PM and released to the acquisition after sign-off		
	Flight plan	Checked by acquisition manager and submitted to client for review		
	Sensor settings	Checked and verified by the acquisition manager		
	Weather conditions	Verified by the operator		
	Survey plan	Checked and verified by the geomatics engineer		
	Base station location	Verified by the geomatics engineer against the contractual requirements for the baseline thresholds		
DATA ACQUISITION REVIEW: These checks are to make sure that the contractor collected the data according to the contractual requirements.	Nominal pulse spacing	Automated checks done by lidar project lead		
	Intensity values	Automated checks done by lidar project lead		
	Data voids	Visual checks by lidar technicians		
	Scan angle	Automated checks done by lidar project lead		
	Swath overlap	Automated checks done by lidar project lead		
	Sensor anomalies	Visual checks by lidar technicians		
DATA CALIBRATION REVIEW: These checks are to ensure that the data meets the contractual accuracy requirements.	GPS-IMU accuracy review	Analysis of solution graphs		
	Vertical accuracy	Vertical report against the check points		
	Relative accuracy	Color coded DZ Orthos for flightline mismatches		
SURFACE QUALITY REVIEW: These checks are to ensure that the lidar point cloud is classified in accordance with the contractual requirements.	Misclassification	Visual inspection of 100% of the data. Final QC is done by reviewing hillshades generated from the classified data.		
	Noise			
	Artifacts			
	Surface consistency			

QC Checklist		Methodology	Contractual Requirements	Department Lead Sign-off
DATA COMPLETENESS & FORMATING REVIEW: These checks are to ensure that all the products listed in the contract are delivered, that they are in the right formats, and that they completely cover the project area.	Delivery layout	Confirmed by the client and signed off by department lead		
	LAS format	Automated check done by lidar lead		
	Classification levels	Automated check done by lidar lead		
	GPS time	Automated check done by lidar lead		
	Horizontal datum	Automated check done by lidar lead		
	Vertical datum	Automated check done by lidar lead		
	Units	Automated check done by lidar lead		
	Coverage checks of deliverables	Visual checks done for each product type by lidar lead		
	Deliverables	Lidar lead verifies that all the deliverables are produced and delivered		
	Breaklines format	Checked by GIS lead		
	DEM format and resolution	Checked by GIS lead		
	Metadata	Checked by lidar and GIS lead		

Option: Contour Development

The lidar and breakline DTM will be processed to generate contours. The area of input data will extend somewhat beyond the intended limits of the contouring. This larger-sized area is used so that when the TIN (triangulated irregular network) is created, it extends past the edge of the deliverable area. This is necessary to ensure that proper interpolation of the contours takes place throughout the area being mapped. Once the contours have been created, they are trimmed back to the intended mapping limits. Sanborn shall ensure the input DTM is hydrologically enforced to ensure a high level of detail with regards to the breaklines for the generation of one-foot or two-foot contours and spot elevations at traditional locations. The drainage enforced contours will meet a vertical accuracy of one-half of the contour level.

Since the same set of masspoints and breaklines are used to create the TIN for adjoining map areas, edge matching errors along the area seams are held to a minimum. Sanborn's proprietary processing software will automatically flag all mismatched contours so that a graphic technician can correct any problems. Smoothing and filtering routines will be used to ensure that contours have a pleasing cartographic experience, while still maintaining geometric accuracy and optimizing the size of the contour database by eliminating redundant vertices in the contour strings.

Contour data will meet the following specifications.

- The attributes of the contour lines will contain a numeric number corresponding to the elevation value that is represented by the line.
- All index contours will be clearly distinguishable and labeled with their elevations given in full feet.
- Every fifth contour will be an index contour and should be clearly distinguishable as such.

- Depression Contours will also be attributed, for both Index and Intermediate
- The elevation of the contour will be easily discernible.
- Contours will be continuous.
- Data will be layered in compliance with the agreed-upon database design, including all symbols, colors, and linestyles.

Contour Delivery

- One seamless GeoDatabase and AutoCAD .dwg file format.
- Metadata for all feature classes will be FGDC-compliant in the XML file format

Contour Quality Control

Sanborn has developed a thorough quality control process to ensure the quality and integrity of all of the topographic data products it produces. Special care is taken to precisely define all requirements for the data to be created, and stringent quality control measures are put in place to ensure that all data meet those defined requirements.

Although normal quality control checks, such as data overlay and aesthetic quality, are performed iteratively for all datasets, Sanborn has also developed a series of automated software checks. These checks are performed each time a data file is processed, or when data is graphically edited. Having these automated checks in place ensures that all errors are discovered during the production process. Specific routines are used within the processing environment to ensure that connectivity of linework is complete and specific layers of line topology are generated, so that line features are free from dangles, overshoots, and undershoots. Sanborn will also ensure that data features meet all topology requirements when the data is placed into the target environment.

Checking for process area edge mismatches is a standard part of all Sanborn projects. Using an automated process, each area is checked against its neighboring areas to ensure that all contours match. After the process completes, a graphics technician digitally reviews each area and corrects any mismatches in line placement or attribution that were flagged by the edgematch routine. This process is repeated until no errors are flagged.

Certification of Compliance with Lidar/Contour Accuracy Standard

Following completion and passage of all internal and independent quality control checks, Mr. Jared Martin, CP, CMS, CST, will certify the product accuracy as meeting the accuracy requirements as set for the project by COAGA 2019. The detailed project plan prepared by the Project Manager will include comprehensive acceptance criteria, including the information outlined in the RFP, and review of interim products, such as the lidar calibration results, that align with our rigorous ISO 9001-based internal quality control and quality assurance methods. Sanborn guarantees that rigorous testing to meet and certify to these standards for quality control for the project and deliverables will be performed. Sanborn has provided a comprehensive description of our quality control procedures following each production step in our workflow in the technical approach.

Sanborn uses a quality-review process for all data to ensure adherence to product specifications, data formats, and data completeness for all deliverables. All data is post-processed in a controlled environment based on strict quality procedures designed to maintain data integrity through highly standardized and controlled procedures for data acquisition, post-processing, and validation. These processes are discussed above, and an overview is provided under the subsection titled Quality Control Process That Will Govern All Aspects of This Project.

Summary of Lidar/Contour Deliverables

Sanborn will provide a copy of all deliverables as outlined in the table below. All data will be quality controlled and in full compliance with the standards and specifications set forth by COAGA 2019 in the RFP.

Summary of Deliverables	
Deliverable	**Description**
Reports	Vertical Accuracy Report Production Process Report (Calibration, Classification, product generation) Control and Calibration Report (FVA, SVA and CVA reporting)
Raw Point Cloud	Calibrated Raw point cloud in LAS 1.4 Geo-referenced header in LAS files Each file size < 2GB (1 file per swath) Adjusted GPS time to allow for unique timestamp for each pulse
Classified point cloud	In LAS 1.4 Classification schema as per the project requirement
Digital Elevation Model (DEM)	DEM in ASCII format
Bare Earth Raster	Hydro-flattened/enforced DEM
First Return (Raster DEM)	1m cell size in 32 bit floating point raster format Tiled delivery
Hydro-breaklines	Esri feature class Geodatabase format (PolylineZ or PolygonZ format) Continuous layer for each delivery area
Hydro-Enforced DEM	Hydro-Enforced DEM
Contours	1-foot or 2-foot contours and spot elevations in Esri Geodatabase and Autocad DWG formats
Metadata	FGDC/USGS compliant metadata for each product type

Metadata: All Products

FGDC-compliant metadata will be provided as part of the project. ArcObjects is used to generate the metadata information in the most efficient manner using semi-automated techniques. At a minimum, the metadata report will contain the following information for each product

- Date(s) of image or lidar collection

- Spatial and spectral resolutions or density
- Spatial accuracy
- Projection and datum of imagery
- Producer contact information for Sanborn
- Methodology descriptions

Metadata will also be included in all geodatabases deliveries for all feature classes in FGDC format. The metadata will include: author information, a description of the dataset, data capture techniques, definitions for all fields, subtypes and domain code descriptions, statement of accuracy, compilation scale, and dates of the completed compilation.

Sanborn has a staff of programmers who can develop applications as needed to ensure that all expectations for file format and metadata are met. Sanborn will coordinate with COAGA 2019 to ensure that all new metadata is compatible with their existing model. We will customize the attributes as needed to include all relevant information and descriptions and ensure that it meets the Federal Geographic Data Committee (FGDC) standards. Metadata files will be delivered in HTML and .XML format.

Equipment: All Products

Sanborn performs data processing functions with external software, proprietary software, and specialized computer systems—they are the foundation of Sanborn's technology. We continuously update and replace our equipment and software as quickly as it becomes available on the market. Our personnel attend and participate in technical conferences and seminars so they can stay abreast of future industry trends.

The combination of Sanborn's extensive hardware collection, commercial and proprietary software, and personnel who are experts in their fields serves to uphold our position as a leading provider of geospatial services and products.

IT Infrastructure

Sanborn has built a world-class Information Technology (IT) infrastructure that increases project productivity and production reliability. The IT infrastructure has been designed to provide a modular pool of computing and storage resources that can be tasked to complete a wide variety of GIS project types. At the core of this infrastructure is a high speed Local Area Network backbone, which allows GIS technicians and an automated distributed processing environment to access a host of computing resources including:

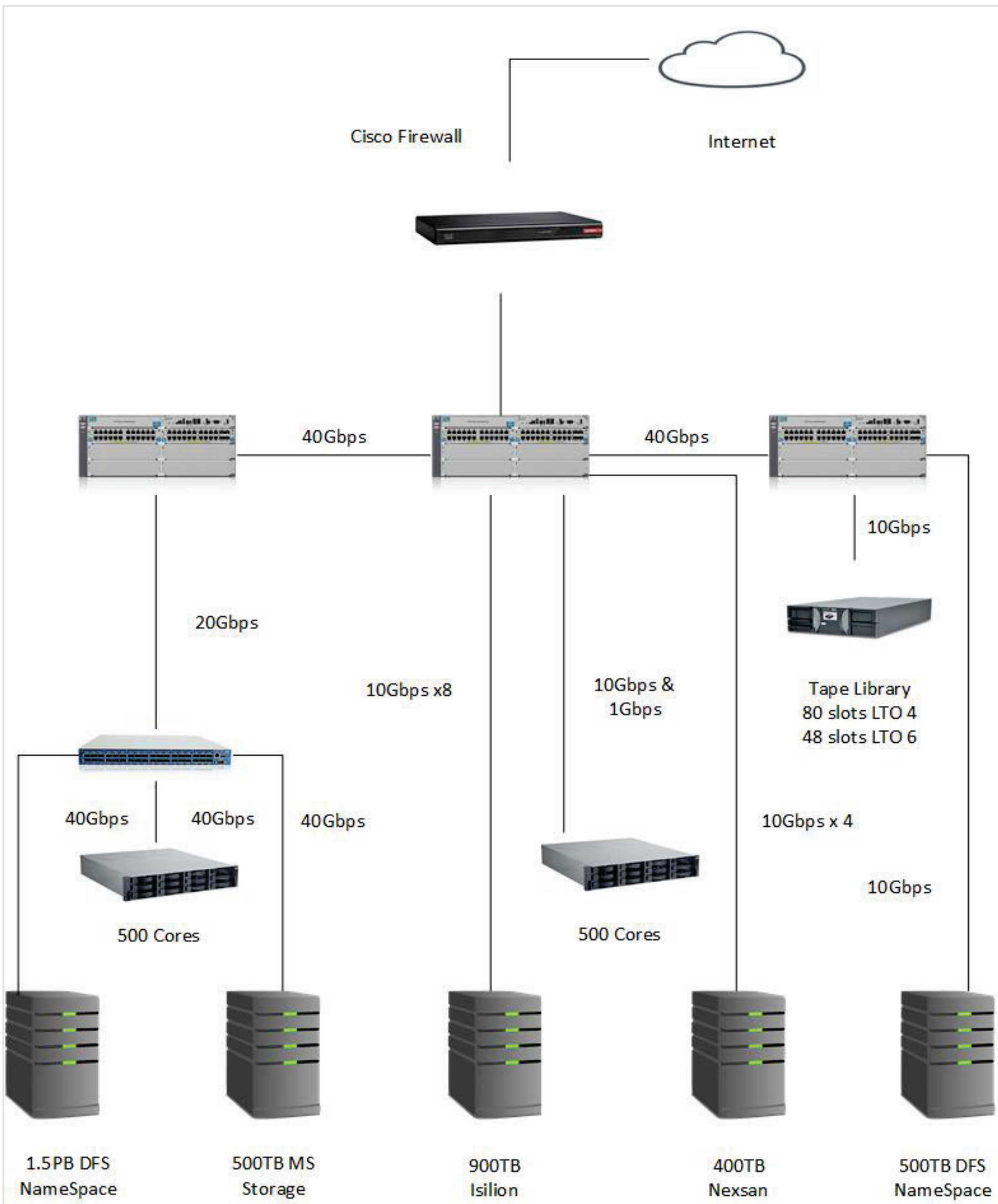
The foundation of Sanborn's IT environment includes:

- A fiber-optic 40Gbps Ethernet backbone and 40Gbps dedicated production Infiniband network ensures high throughput access to application and storage servers.
- A high throughput parallel processing server farm with 300 dedicated computer nodes and 200 additional CPUs as needed for batch processing of GIS data.
- More than 4 Petabytes (4000 Terabytes) of distributed data storage. While storage is physically distributed, Sanborn uses an overarching file location abstraction system in order to present a centralized logical view of the storage throughout Sanborn's enterprise. This

technique allows storage to be added at many different levels without major network or workstation reconfiguration.

- The ability to add idle user workstations during off hours to the distributed processing environment, providing more than 350+ nodes of computing power to the distributed batch processing environment.
- A fully automated real-time network monitoring environment that checks the health and utilization levels of all servers, storage systems, distribute processing systems, and the network backbone. Technicians are automatically notified of any failure or anomaly 24 hours a day.

An example diagram of Sanborn's network has been provided below.



Sanborn's IT infrastructure

Sanborn has increased its throughput by incorporating distributed processing technology (a.k.a. "cloud computing"). The basic system has been in place for more than five years at Sanborn. Distributed processing technology takes advantage of more than 300 computer processors in the company to process data in its various stages simultaneously. Distributed processing functions are applied to all of our image and ortho processing routines and essential to maintaining a large capacity production floor.

Acquisition and Mapping Equipment

The abundance of Sanborn's resources allows for simultaneous processing of numerous major projects without impacting production schedules. This means we can save our customers time and money without sacrificing quality. Sanborn owns and operates all of the equipment listed in the following tables.

Data Acquisition

Hardware/Software	Item Name/Model or Version	#	Remarks
Acquisition Resources			
Aircraft	Cessna TU206F	1	Sanborn has numerous additional flying partners with high performance aircraft outfitted for aerial photography and lidar missions
	Cessna TU206G	2	
	AeroCommander 680W	1	
	AeroCommander 690A	1	
	Piper Navajo PA	3	
	Leptron Avenger B	1	Unmanned Aerial Vehicles (UAV)
	DJI Inspire 1	1	
	DJI Phantom 3 Professional	1	
Cameras/Sensors	Vexcel UltraCam Eagle	3	100mm w/ Ultranav FMS and Type 46, non-ITAR IMU
	Leica ALS-70	1	Lidar sensor w/ iPAS and LN200 IMU
	Leica ALS-70	1	Lidar sensor w/ Honeywell MicroIRS, non-ITAR IMU
	Leica RCD30 Aerial Camera System	2	Enables simultaneous lidar/aerial imagery collection
	MIDAS Oblique Imagery Sensor (Nikon)	3	50mm Nadir, 85mm oblique, POS-AV/Track'Air w/ LN200 IMU
	MIDAS Oblique Imagery Sensor (Nikon)	1	50mm Nadir, 85mm oblique, POS-AV/Track'Air w/ Type 46, non-ITAR IMU
	MIDAS Oblique Imagery Sensor (Nikon)	1	135mm Nadir, 180mm oblique, POS-AV/Track'Air w/ LN-200 IMU
	I-One oblique sensor	1	POS-AV w/ LN200 IMU
	Vexcel UltraCam D	2	Large Format Digital Camera
	Canon D5 Mk3	1	Digital Camera for use w/ UAV
	Sony a7mk2	1	Digital Camera for use w/ UAV
Flight Planning, Navigation, and ABGPS Post Processing	Track'Air Flight Management System/FM	2	Used for pinpoint aerial photography
	Applanix POS/AV w/IMU System/510	5	
	Garmin Navigation System/GPSMAP 496	2	Navigation and weather radar
	Piccolo Command Center	1	Flight management system for Leptron UAV
	DJI GO	1	Flight management system for DJI UAV
	Pix4D	1	Flight management system for DJI UAV
GIS Software	Applanix POS PAC/FM	11	Used for ABGPS post processing
	Waypoint GrafNav Kinematic GPS Post Processing/FM	6	Used for airborne GPS (AGPS) post-processing
Field Survey			
3D Terrain/Feature Scanning System	Trimble 3-D Laser Scanner/GX Advanced	1	Scanning motorized through 360°, 200 m optimized range, 350 m OverScan capability, 700 m addressability, Up to 5,000 points/sec, Dynamic filtering
	Trimble Realworks	1	Terrestrial Lidar Software that filters lidar , extracts linework , geometry, and solids
	Auto Correlation Filtering SW/FM	1	This SW utility can combine photogrammetrically digitized mass points and breaklines with lidar and terrestrial 3D imagery data. Differential weighting in the least squares surface estimation accommodates data of varying accuracy. AC filtering operates on all file types
Misc. Equipment	Pentium Laptop Computers/Various	4	Sanborn has various field survey vehicles, ancillary survey equipment (tripods, etc.), and equipment such as augers for setting permanent monumentation
	Field Vehicles/Various	4	
	Tripods/Various	34	
	Two-Way CB Radios/Motorola	5	
GPS Equipment and Software	Novatel DL4+ GPS receivers	12	Receivers that are usually used for ground control/geodetic surveys. Many have RTK capability, TSCE data collectors, pen-based computers, and software
	Trimble R8 Model 3 with TSC3 Trimble Access Base Rover GLONASS Receiver Kit UHF	1	
	Trimble SPS850 and R8 GNSS Receivers w/ RTK HPB450 Radios, and RTK cellular modems	2	
	Trimble RTK Dual Frequency Rover & Radio/5700	5	
	Digital Level/NA2000	1	Sanborn has a full array of specialized high precision equipment including optical plummets, translation stages, and optical metrology equipment for operations such as deformation monitoring
	Trimble TSC2 Survey Controller	2	
	Handheld GPS Units (Trimble, Garmin, Magellan)/Var.	5	
	Topcon SPS850	3	
	Leica Total Station/T1800	1	
	IPAC Pocket PC/H2200	1	
	Trimble Business Center 3.10	2	General purpose processing/data management SW, incl. post-processing of static geodetic quality GPS data
	Trimble GPSurvey	5	Post-processing of static geodetic quality GPS data
	Airlink Cellular RTK System	1	

* Full Maintenance (FM) - in most cases SW is upgraded and supported to latest available version

Photogrammetry			
Hardware/Software	**Item Name/Model or Version**	**#**	**Remarks**
Aerial Triangulation and Compilation			
Softcopy Photogrammetry Hardware and Software	Bentley Microstation	15	Version v8i and CONNECT
	DATEM Summit Evolution Stereo Softcopy Station	2	
	Intergraph ISAE, ISSD, ISFC, ISDC	*	Photogrammetry Compilation modules *Temporary licenses can be obtained on an as-needed basis
	Intergraph Softcopy Photogrammetric Workstation/SSK	*	Stereo Model Compilation workstations *Temporary licenses can be obtained on an as-needed basis
	Trimble INPHO Match-AT	4	Version 5.5.1
	DATEM-Summit Evolution Professional Microstation	2	
	DATEM-Summit Evolution Feature Collection Microstation	2	
	DATEM-Summit Evolution Feature Collection ArcGIS	3	
	DATEM-Summit Evolution Feature Collection AutoCAD	1	

GIS			
	Item Name/Model or Version	**#**	**Remarks**
Graphic Editing/GIS			
GIS Software & Development Software	ArcGIS/INFO and Associated Modules/FM	54	Version 10
	ArcCOGO/FM	2	Version 10
	ArcEditor/FM	3	Version 10
	ArcIMS/FM	3	Version 9.0
	ArcLP360/FM	4	Version 10
	ArcPAD/FM	8	Version 6
	ArcPress/FM	1	Version 10
	ArcPublisher/FM	1	Version 10
	ArcScan/FM	1	Version 10
	ArcSDE/FM	2	Version 10
	Adobe Acrobat Professional/FM	20	7.0
	Adobe Lightroom	37	4.0 and 6.0
	CodeSmith Station/FM	1	4.1
	Data Interoperability/FM	4	Version 9.3
	EDN/FM	7	Version 9.3
	ERDAS Imagine/FM	5	9.1
	ET Geowizards /FM	2	9.8
	GeoStatistical Analyst/FM	3	Version 9.3
	GeoCue/FM	5	5.0
	Global Mapper /FM	2	6.0
	PLTS GISDataReviewer/FM	1	Version 9.3
	Python/FM	12	Version 2.5
	CommVault/FM	3	Simpana 10
	SDE Connects/FM	11	Version 9.3
	Spatial Analyst/FM	25	Version 9.3
	Survey Analyst/FM	1	Version 9.3
	3D Analyst/FM	9	Version 9.3
	Visio Professional/FM	3	2000
	Visual Basic/FM		VB.net
CADD			
CADD Software	AutoCAD Map 3D 2009 /FM	2	2009 and 2017
	AutoCAD (Including Raster Design, Survey, Civil Design, Civil 3D, and Map 3D)/FM	3	2004 and 2017
	Datem AutoCAD Map Editor/FM	1	2004
	Bentley Microstation/FM	15	Version v8i and CONNECT
	Datem Microstation Map Editor/FM	1	Version 8

Orthophotography			
Hardware/Software	**Item Name/Model or Version**	**#**	**Remarks**
Ortho Processing Software and Hardware	Adobe Photoshop/FM	29	Version CS5, 2015, and 2017
	Adobe Illustrator/FM	10	
	APS 3-D Workstation	1	w/3D glasses and emitter
	APS Graphic and Image Processing/Editing System/FM (Sanborn Proprietary Software)	Unlimited	APS software is used for editing and enhancing data and to develop topology and continuity for quality control and aesthetic enhancement. Produces accurate, consistent, and aesthetic GIS products for our clients
	Bentley Descartes Image Processing/FM	1	
	Blue Marble Raster Transformation/FM	1	
	Blue Marble Coordinate Calculator/FM	1	
	Cubist/FM	3	
	Ecognition Professional/Image Analysis/FM	7	
	ERDAS Imagine/FM	15	Version 2011 Robust image processing and GIS modeling software for analyzing a variety of aerial and satellite image products including panchromatic and multispectral/hyperspectral imagery and RADAR. Also supports complex 3D modeling and visualization applications
	Feature Analyst/FM	2	
	Imagination/FM	1	
	Metro Express – High-Speed Imaging Process System/FM (Sanborn Proprietary Software)	Unlimited	Internal Sanborn software that creates high quality enhanced orthoimagery, including automated true orthophoto production
	Metro ortho-processing software	Unlimited	
	MrSID (GeoExpress & Geospatial Encoder)/FM	14	
	Trimble INPHO Applications Master	Unlimited	Version 5.5.1
	Trimble INPHO Seam Editor	3	Version 5.5.1
	Trimble INPHO OrthoVista/FM	3	Version 5.5.1
	See5/FM	3	
	Softdesk CAD-Overlay GSX/Image Processing/FM	4	

Lidar Data Acquisition Equipment			
Hardware/Software	**Item Name/Model or Version**	**#**	**Remarks**
Field Survey			
Survey Equipment	Laptop Computers/Various	4	Sanborn has various field survey vehicles, ancillary survey equipment (tripods, etc.), and equipment such as augers for setting permanent monumentation
	Field Vehicles/Various	8	
	Digital Level/NA2000	1	Including a pair of bar-coded invar rods; 8 geodetic levels in total
GPS Equipment and Software	Trimble RTK Dual Frequency Rover & Radio/5700/Trimble 4000SI w/ L1 L2 Ant	5	Receivers that are usually used for ground control/geodetic surveys. Many have RTK capability, TSCE data collectors, pen-based computers, and software
	Delorme EarthMate USB Antennas/LT-20	2	Sanborn has a full array of specialized high precision equipment including optical plummets, translation stages, and optical metrology equipment for operations such as deformation monitoring
	Handheld GPS Units (Trimble, Garmin, Magellan)/Various	5	
	Javad Geodetic Grade Dual Freq Receivers/Legacy-E	4	
	Fujitsu Stylistic Tablet PC/ST5000	1	
	Leica Backpack Unit/GS5+	1	
	Leica Total Station/T1800	1	
	Trimble Geomatics Office/FM / GPSurvey / Trimble TDC1 Survey Controller & SW/FM	9	Trimble's newest general purpose processing/data management software, including the post-processing of static geodetic quality GPS data / Post-processing of static geodetic quality GPS data
Acquisition Resources			
Sensors	Leica Lidar Sensor/ALS70 (MPia)	2	200 kilohertz laser repetition rate, 0-70 degree swath angle, Four returns recorded, Intensities recorded, Flying height: 200m-6,000m
	Applanix DSS 439	1	39 megapixel camera, RGB or IR image, 60 mm lens
AGPS/INS	Novatel GPS Receivers/Millennium DL, DL4 + L1/L2, 600	12	The Millennium receivers are used for airborne GPS/INS operations and Lidar support
	Applanix POSproc/FM	11	Advanced Kalman filtering software—used for postprocessing/combining GPS and IMU data.
	QCoherent Lidar/FM	10	
Processing			
Processing Software	ALS Post Processor	8	Raw Leica Range data processing and calibration software
	ALTM Lidar Processing – Realm (3) Dashmap (2)	5	Raw Optech Range data processing and calibration software
	ALTM-NAV	3	Flight planning and flight management software for Optech
	Applanix POS PAC 8.1	11	
	ArcInfo/ArcEditor (3D Analyst, Spatial Analyst)	30	
	GeoCue (Lidar Cuepak)	10	Lidar Production management and lidargrammetry software
	Qcoherent L360	10	Manual QC/Editing of Lidar and Product generation. Filtering, project management and visualization
	Virtual Geomatics VG4D	4	
	TerraModel DTM/Contour	9	Generation of DTM and Contours
	Terra Solid Terramodeler / TerraScan	17	For classification and manipulation of lidar data
	Waypoint GrafNav Kinematic GPS Post Processing	5	Used for airborne GPS (AGPS) post-processing

Section 3 – Management Proposal

Project Management/Coordination with Participating Members of COAGA 2019

Sanborn's project management approach rigorously applies the Project Management Institute (PMI) model. Sanborn understands that an upfront investment in planning results in the best outcome for the entire project lifecycle. The PMI model encompasses the following knowledge areas and process phases:

- Integration
- Scope
- Time
- Cost
- Quality
- Human Resources
- Communications
- Risk
- Procurement

Designated Single Point of Contact

Sanborn's Project Manager, Bridget Marcotte, PMP, has been assigned as COAGA 2019's single point of contact and will serve as your primary liaison with Sanborn operations, staff and management. Ms. Marcotte has over 13 years of experience with diverse geospatial mapping projects. She has extensive production and project management experience including statewide data, geospatial planning, and imagery/lidar/planimetric projects, and served as project manager for the COAGA 2015 project, as well as the 2016 and 2018 City of Edmond mapping projects.

Ms. Marcotte is thoroughly familiar with the requirements and specifications and, will be responsible for project definition, production oversight, scheduling, quality management, and financial and contractual management. Communication methodology for communication with all participants is detailed in the Communication Management subsection below, following the Project Planning subsection.

Project Initiation

Project definition at Sanborn begins with the preparation of a project charter that encompasses all elements of the program. The project charter establishes the overall goals, vision, organizational structure, project structure, deliverables, management plans and approach, technical baseline, schedule, cost, subcontract management, quality, and other key elements of the program. All the methods used to plan, monitor, and control the project are also identified in the project charter.

A key element of the project definition is the development of the project schedule in our earned value management (EVM) system, in addition to multiple supplementary tracking systems. This project management and production tool is used to develop and track all project resources and the schedule throughout the life of the project. The EVM schedule is the single source for all project status and tracking throughout the life of the project. A baseline contractual schedule is maintained in addition to multiple scenario schedules.

Project Planning

Sanborn believes that the key to any successful project is continuous customer communication. Soon after contract award, Sanborn will request a preliminary planning meeting to identify any specific items that may have arisen after the original RFP was released. Once this information is gathered and the project charter is complete, Sanborn will request a "kickoff" meeting where Sanborn's management team and appropriate Sanborn production staff will meet with appropriate COAGA 2019 staff to:

- Review the technical requirements of the project against the proposed technical plan contained in Sanborn's proposal.
- Review the sources that are to be supplied by COAGA 2019 against the requirements and expectations of Sanborn's proposed work plan.
- Review the acquisition plan requirements and flight plans.
- Review the preliminary work plan (and the quality control processes and procedures) as presented in Sanborn's proposal against defined delivery areas or work packages.
- Review the estimated resource plan.
- Review the project-specific Quality Plan presented at the meeting by Sanborn. Included will be a review the product acceptance procedures, methods and criteria that will be used by COAGA 2019 to determine product conformance with product specifications.
- Review the proposed project schedule and finalize interim and final delivery dates
- Review the schedule requirements by specific work tasks and the interdependencies of the sources of information to be supplied by COAGA 2019
- Define the parameters of a pilot or prototype project where the proposed procedures will be tested for their ability to meet product specifications and/or the ability of the product specifications to meet the needs of COAGA 2019
- Define a formal change management process designed to effectively and efficiently track proposed modifications to contracts. This process will allow COAGA 2019 to make cost and benefit tradeoffs based on an analysis of the requested changes. It allows for the design, development, and implementation of modifications to production processes and procedures to be made in a controlled manner.
- Define all communication protocols and procedures that are necessary for effectively ensuring that both parties to the contract are informed about the production departments' progress on each project task, that the sources are effective for the purpose intended, and the status of deliverable product reviews by COAGA 2019.

We anticipate that the kickoff meeting will be held via conference call, but we welcome a site visit to our production facilities at any time throughout the course of the project.

Communications Management

Sanborn will maintain procedures throughout the project for tracking and reporting progress in the data conversion and update process. Sanborn will communicate and work with participating members of COAGA 2019 to resolve issues if source anomalies are found. Sanborn proposes to accomplish this in several ways, including conference calls and interactive web meetings depending on what is most appropriate and efficient to discuss and resolve the problem. This process will be formalized during the project kick-off meeting and may be modified thoughout the project as needed.

Customer communication and status reporting is the most important aspect of project management. The continuous communication between Sanborn and COAGA 2019 will provide insight to the project process and eliminate gaps in communication on technical and schedule issues. Sanborn has a proven method of communication with our customers, and will review with COAGA 2019 the best method to ensure constant contact throughout the project lifecycle.

Communication requirements will be incorporated and documented in the work plan. The specific requirements for each project are unique; therefore, the tracking and reporting tools and procedures necessary for effectively managing the project are established specifically for COAGA 2019's project and maintained throughout the term of the contract.

Meetings and Conference Calls

Meeting minutes from project team meetings and conference calls will be produced and distributed by Ms. Marcotte. These minutes will include descriptions of the issues discussed during the meeting, their resolutions, and the necessary follow-up. All project records, including correspondence, reports, invoices, and specifications, will be maintained in the project files by Ms. Marcotte.

Project Status Reporting/Resolution of Source Anomalies

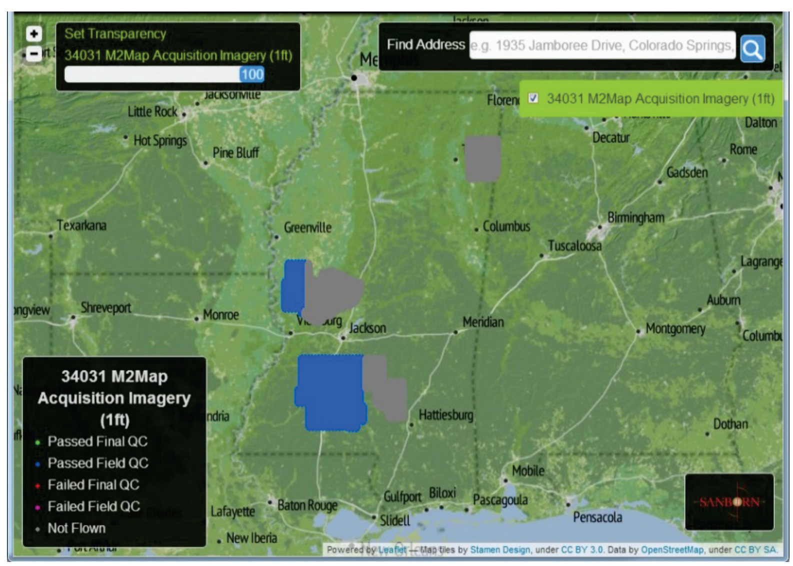
Sanborn is committed to successful internal performance management and to providing customers with easy access to the status of their projects. We accomplish this by using a variety of proven tools.

Project Status Reporting is one of the most critical aspects of communication for large projects with many players and variables. As a result, Sanborn utilizes four primary technologies to provide update information about the project to COAGA 2019, including real-time web-based tracking reports.

1. **Written Status Reports –** Ms. Marcotte will submit a monthly Project Status Report to provide project team members with a common understanding of the important issues, procedures, and goals associated with the project. The report summarizes project activities completed over the past reporting period and those planned over the next similar time period. Information addressed in the Project Status Report includes the following:
   - Major activities completed during the most recent reporting period
   - Summary of data production status, including but not limited to listing of data accepted by COAGA 2019 and the status of COAGA 2019's review of delivered data
   - Description of current project issues and procedures

- Activities to be completed over the next reporting period
- Data production forecasts for the next reporting period
- List of requested action items
- List of outstanding issues/action items

2. **Status Calls and Resolution of Source Anomalies**: It is understood that inconsistencies and anomalies between source materials and specifications will occur. Sanborn will be responsible for bringing such issues to the attention of COAGA 2019's designated project manager. Weekly status calls can be held with COAGA 2019 to coordinate project activities and to ensure communication of any issues noted in the status report, including these inconsistencies or anomalies. Exact times will be established with COAGA 2019 during the project initiation meetings. It is the Sanborn project manager's responsibility to facilitate this call, document new actions, address the status of open issues, and assign action items. A sample agenda is as follows:
    - Major issues and action items completed for a specified time period
    - Critical issues and actions not completed and their potential impacts including, but not limited to, COAGA 2019's review of deliverables and the schedule for source data delivery
    - Production status
    - Action items for next reporting period
    - Upcoming action items and questions
3. **Web-Based Reporting/Program Status via Sanborn's Status Portal** – Sanborn recognizes the importance of enabling our clients to gather information on the status of their projects during acquisition. Being able to anticipate deliveries and to gather information on your projects status without relying on project management or production personnel can be very important (if not critical) at times. Understanding this need, Sanborn developed a system that provides our clients with the ability to view the status of their acquisition projects through an Internet connection.



The Status Portal is Sanborn's method of visually tracking projects internally while at the same time allowing our clients to view the status of their projects. This browser-based viewing system allows clients to check the status of their projects at any time. The Status Portal, which is strictly for viewing purposes, is accessible via the Internet using standard web browser. No additional client-side software is required. Our Program Manager will ensure the Status Portal website is updated on a daily basis for acquisition.

The web-based online status viewer will reflect a status for each tile or block as appropriate. Information posted to the status reporting site includes the progress for aerial imagery acquisition.

4. **Web-based Collaboration Site –** Our proposal assumes we will develop a project website to be accessible through our internal Intranet as well as the Internet. This tool will facilitate communication, document control, and standardization of procedures for both internal and external project /task management. This website will be designed specifically for COAGA 2019's project, and confidentially secured by user login and password.

   Project home pages provide hyperlinks to project reference documents, specifications, productivity and quality data, project status reports, technical support requests, and can be the primary mechanism for distributing status reports. Instituting this for COAGA 2019 would greatly improve project communications and tracking. This technology will benefit this project and COAGA 2019 by:

   - Providing easy distribution of project updates, alleviating total reliance on email, faxes, etc.
   - Providing summary and detailed level reporting, as well as sorting information by category.

Responsibilities

Sanborn staff members are aware of what they are authorized to undertake and are responsible for achieving. This is ensured by documentation of responsibilities and authorities in specific procedures. All employees are responsible for following applicable policies, procedures, and work instructions. Additionally, every employee has the responsibility and authority to:

- Initiate action to prevent the occurrence of any nonconformities relating to product, process, and the Quality Management System
- Identify and record any problems relating to the product, process, and the Quality Management System
- Initiate, recommend, or provide solutions through designated channels
- Control further processing and delivery of products until the deficiency has been corrected
- Ensure that the COAGA 2019's source materials and other property, including intellectual property, is logged, utilized, stored, and returned in a controlled manner

Roles and Responsibilities of the COAGA 2019

Sanborn proposes that the COAGA 2019's roles and responsibilities under this program will be to:

- Coordinate and communicate with Sanborn
- Process all contractually-related documents in a timely manner
- Review Sanborn's flight plans and related documents, and provide comments or approval in a timely manner
- Respond in a timely manner to requests for information, data, and meetings or conference calls

- Perform reviews and quality control checks of interim and final deliverables in a timely manner and communicate the results to Sanborn
- Review and pay Sanborn's invoices in a timely manner.

Quality Management System

Sanborn has designed a comprehensive Quality Management System (QMS) based upon ISO-9001 requirements and standards. ISO-9001, a Quality System Standard, is a series of five international standards that provide guidance in the development and implementation of a specific quality system. With Sanborn's thorough QMS processes, COAGA 2019 is assured that:

- The requirements and specifications of the project have been thoroughly and rigorously evaluated and documented
- The production processes and procedures employed for the project are appropriate and adequate to produce the results intended
- The production processes and procedures are controlled and results will be consistent and repeatable
- Documentation will be maintained that allows for evaluation of the processes and procedures to eliminate the source of nonconformities and to facilitate continual improvement of the processes and procedures
- Adequate facilities are available to meet the needs of the project
- Sufficient numbers of competent and adequately trained employees are working on the project

Sanborn's Quality Management System has been developed to ensure that adequate and continuous control is in operation for all activities affecting product quality. Where specific regulatory requirements affect our processes, our procedures and instructions will be designed or revised to meet such requirements. Sanborn employs methods and techniques that foster continuous improvement and good business practice.

Sanborn places an emphasis on problem prevention rather than dependence on detection after occurrence. Every effort is made to perform operations and quality-related activities correctly the first time. The Quality Management System includes a formal review of the parameters affecting product quality from conception to contractual fulfillment. Whenever necessary, corrective and preventive actions are implemented to ensure continuous improvement.

Staffing

Sanborn's experience with and ability to manage complex geospatial oblique and ortho imagery programs is due in no small part to significant investments in human resources. The Sanborn team of nearly 125 geospatial technology and management professionals possesses an enviable resume of project experience, significant educational credentials, and registration from government agencies and leading industry associations.

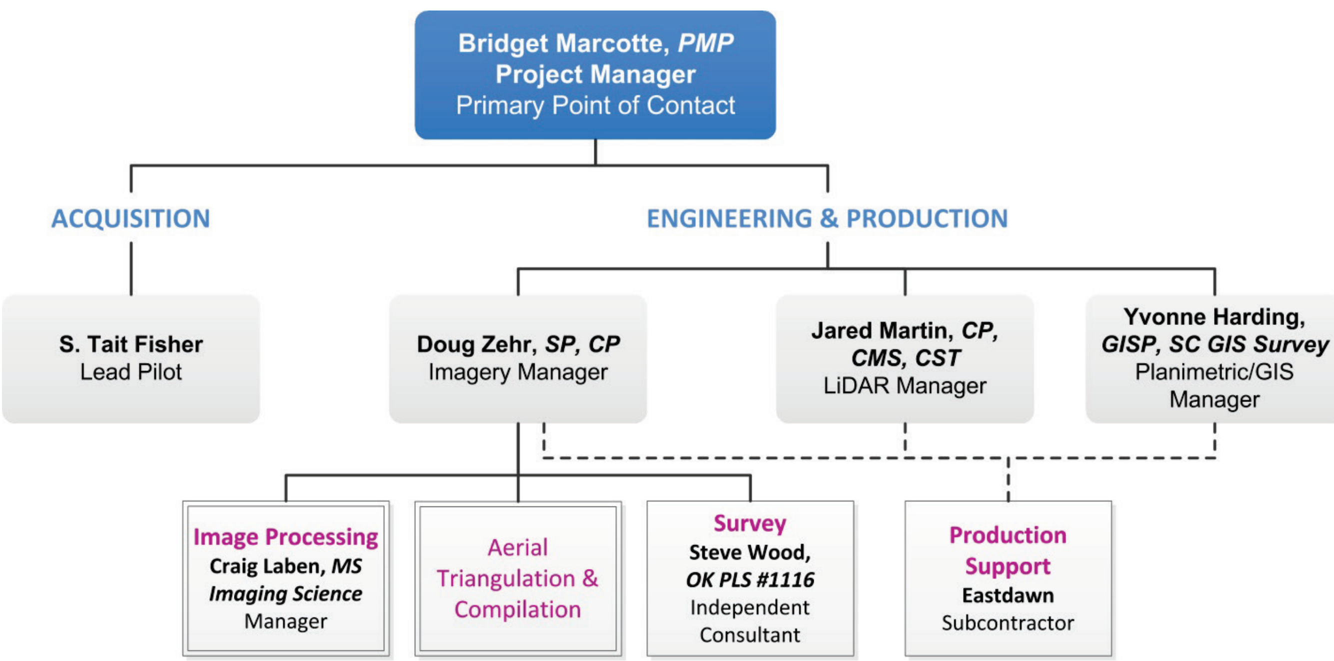
Key Personnel

Sanborn uses established, cohesive teams that streamline the production process significantly. Under this approach the project benefits from the synergy of a proven team, which is critical to achieving maximum efficiency for cost-effective solutions. Sanborn's staffing structure ensures that project requirements are met. We select project team members based on the following criteria:

- Goals of COAGA 2019
- Project management experience
- Reliability in meeting schedules
- Technical expertise
- Commitment to quality

The COAGA 2019 project will be completed out of our main production facility and corporate headquarters located in Colorado Springs, Colorado, with production support from our subcontractors. The technical managers and production staff all work together in a single facility, which creates the ideal conditions for effective communication and productive workflows. Also of note, we have several Certified Photogrammetrists on staff, which will help ensure COAGA 2019's products conform to the required mapping standards.

The following organizational chart highlights key project personnel and their expertise. Full resumes for the proposed key personnel, including subcontractors, are provided in the Appendix of this proposal response.



Key Personnel: Brief Overview

A brief overview of key personnel assigned to the COAGA 2019 is provided below and detailed resumes are provided in the Appendix.

Project Manager

Each project is assigned a project manager with responsibilities including customer communication, scheduling, and ensuring adherence to the project specifications. The project manager works with department managers and production staff in establishing an implementation plan that outlines the project's technical requirements. The department managers draw on their production staff, as required, to meet the project objectives. The specific list of employees involved in any given project can be extensive with up to 25 employees or more, depending on the project size and schedule.

Sanborn's Project Manager Ms. Bridget Marcotte, PMP, will be COAGA 2019's single point of contact and will serve as your primary liaison with Sanborn operations staff and management. Ms. Marcotte has more than 13 years of experience in the GIS/mapping industry, utilizing remote sensing and GIS technology to deliver innovative and quality geospatial programs. She has extensive production and project management experience including statewide data, geospatial planning, and lidar/imagery/planimetric projects. Ms. Marcotte successfully took over and completed the management of the COAGA 2015 program in 2015, and also managed the 2016 and 2018 City of Edmond programs.

As a certified Project Management Professional (PMP), Ms. Marcotte's skills, knowledge, and abilities are recognized by the Project Management Institute (PMI). In general, Ms. Marcotte will be responsible for project definition, production oversight, scheduling, quality management, and financial and contractual management.

Data Acquisition and Aircraft Operations

Mr. Fisher has more than 35 years of experience as a pilot operating in a wide variety of aviation operations and holds an Airline Transport Pilot certificate. Prior to Mr. Fisher's career with Sanborn, he has been employed as both a UPS and USPS cargo pilot delivering freight throughout the western US region. Mr. Fisher has also gained extensive experience operating nationwide as an FAA part 135 charter and air ambulance pilot in both Learjet and King Air type aircraft. Mr. Fisher has also been employed as an airline pilot with United Express and has always maintained current certificates and ratings as a Flight Instructor with Single Engine, Multi Engine, Instrument, and Advanced Ground Instructor Ratings. At Sanborn, he manages and coordinates crew movement and aircraft maintenance, and oversees data tracking and recordkeeping for an extensive fleet of aircraft ranging from single engine Cessnas to twin turbine aircraft.

Photogrammetry/Orthoimagery

Mr. Doug Zehr, CP, SP, has 27 years of industry experience and is Sanborn's Chief Photogrammetrist. Mr. Zehr has excellent organizational habits, outstanding photogrammetric knowledge, and professional dedication. His responsibilities include project planning and design, overseeing aerial triangulation, and the support of photogrammetric and Lidar production processes. Mr. Zehr has superior technical competence and highly effective personnel management that has a positive developmental impact on all the staff under his management. He possesses communicative and technical competencies that have a positive impact on the entire organization. Mr. Zehr's expertise with least square adjustments, AGPS/IMU processing technologies and overall production process flow has garnered industry recognition. Mr. Zehr is not content to just deliver a good solution, but works tirelessly in finding the best solution, using all of the tools available and working with his co-workers until there is team acceptance. He searches for the most efficient methods possible and then has the experience to accurately assess both the advantages and shortcomings of new methods. During his time with Sanborn, he has increased processing efficiencies by more than two times while maintaining the accuracy requirements and quality expectations of Sanborn's COAGA 2019s. During his career, Mr. Zehr has completed a multitude of ASPRS/USGS/FEMA-related topographic data development programs including the Sanborn references used within this proposal.

Image Processing

Mr. Craig Laben has over 20 years of experience in remote sensing, GIS, image processing, geospatial analysis and geospatial product quality assurance. He has extensive knowledge of commercial and government satellite and aerial EO, MS, IR and radar imaging systems data and their applications. In addition, Mr. Laben has developed algorithms, techniques, processes and metrics to improve the image quality, accuracy and intelligence value of geospatial products. For all aerial projects within Sanborn's mapping operations, Mr. Laben coordinates activities between the flight acquisition team and the production team, and ensures that image quality and accuracy standards are met. Mr. Laben works with the GPS-IMU and Image Quality Control (QC) teams to optimize workflow and to develop more efficient processes, improving data ingest and QC processing times.

GIS Operations

Ms. Yvonne Harding, GISP, SC GIS Surveyor, has been employed by Sanborn continuously for over 18 years and is currently the GIS Operations manager. She is very experienced in all phases of photogrammetry and has extensive experience in geospatial mapping, including generating new or updating existing DTM models, orthophotography and 3D planimetric extraction. She will manage the development of a new or updated DEM, as well as the planimetric updates for Edmond and Norman. She managed production for the previous City of Edmond projects in both 2016 and 2018.

Lidar Operations

Mr. Jared Martin, CP, CMS-Lidar, CST, has more than 7 years of experience in the remote sensing profession. He has supervised and worked on programs ranging from multi-year large area projects to small area, high accuracy, quick-turn emergency response projects. During his career he has refined his technical and managerial expertise by accumulating working knowledge in both small and large business environments. Mr. Martin has demonstrated his subject matter expertise in utilizing Lidar data and technology from multiple platforms by developing and improving existing business processes resulting in better geospatial decision making.

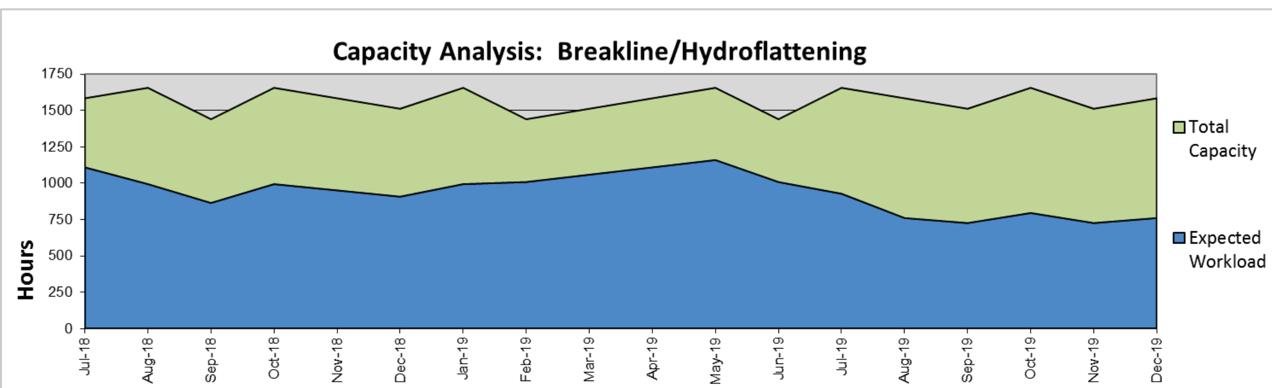
Available Resources

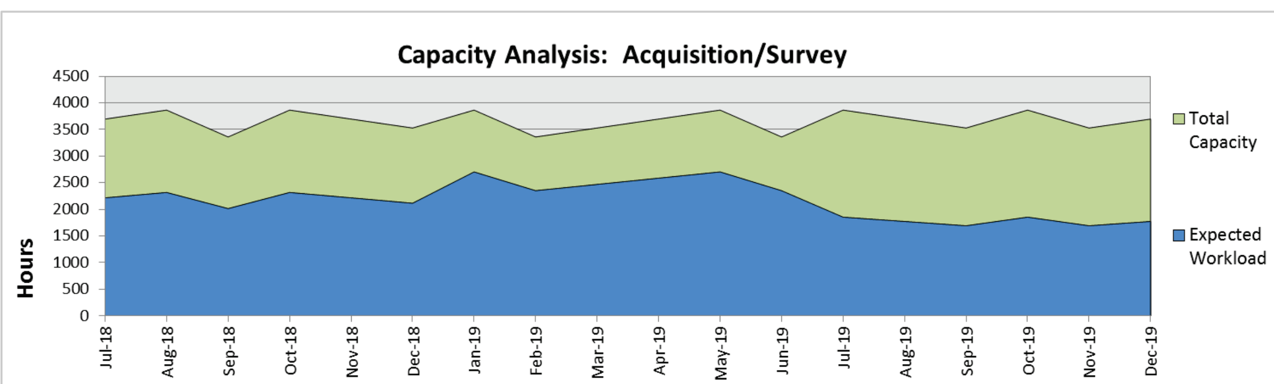
The combination of Sanborn's extensive hardware collection, commercial and proprietary software, and personnel who are experts in their fields, serves to uphold our position as a leading provider of geospatial services and products.

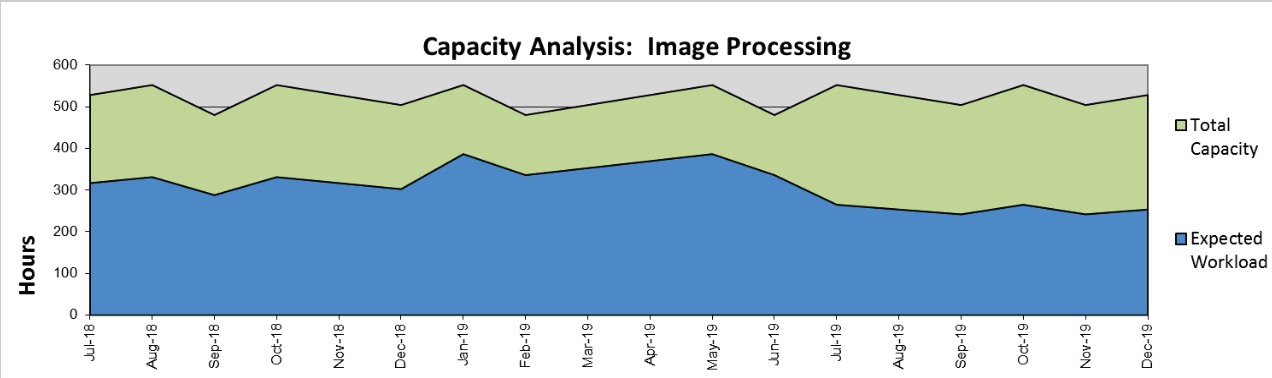
Sanborn's earned value management (EVM) environment, in addition to multiple supplementary tracking systems, enables integrated management of the entire project lifecycle. This project management and production tool is used to develop and track all project resources and the schedule throughout the life of the project, from design and proposal development, to implementation, and change management. Project schedules and resource allocations are modeled in the EVM as early as the proposal stage, then developed and maintained over the entire life of the project. For the COAGA 2019 program, as the collection and processing moves through the timeframes, updates to the EVM allow Sanborn to reallocate resources if necessary and to direct additional assets to cover equipment failures, weather problems or changes in the capacity plan as a result of changes in the collection activity.

Sanborn has the ability to assume the significant scale of the COAGA 2019 project with our available resources and key personnel. Sanborn's current and anticipated workloads do not directly conflict with the COAGA 2019 acquisition and production window. Sanborn actively tracks total capacity, capacity against existing workload, and capacity against existing workload with new anticpated programs; and, performs six- to twelve-month look-ahead analyses in order to adjust for variation in the need for production resources proactively and dynamically, and ensure that resource adjustments do not need to be made in "crisis mode" in order to ensure schedule compliance.

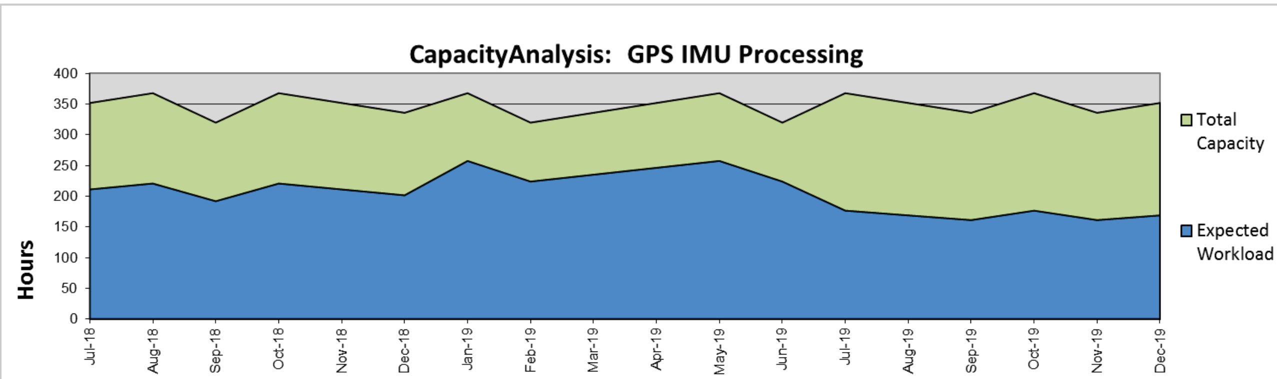
Below are graphs documenting our EVM resource analyses. The graphs show significant capacity for airborne data (imagery and Lidar) acquisition, airborne GPS/IMU processing, image processing (pre-rectification), Lidar processing, compilation/GIS (new or updated DTM and planimetric update), aerotriangulation, and imagery post processing (orthorectification). Based upon this analysis, Sanborn has plenty of capacity to take on the proposed scope of work.



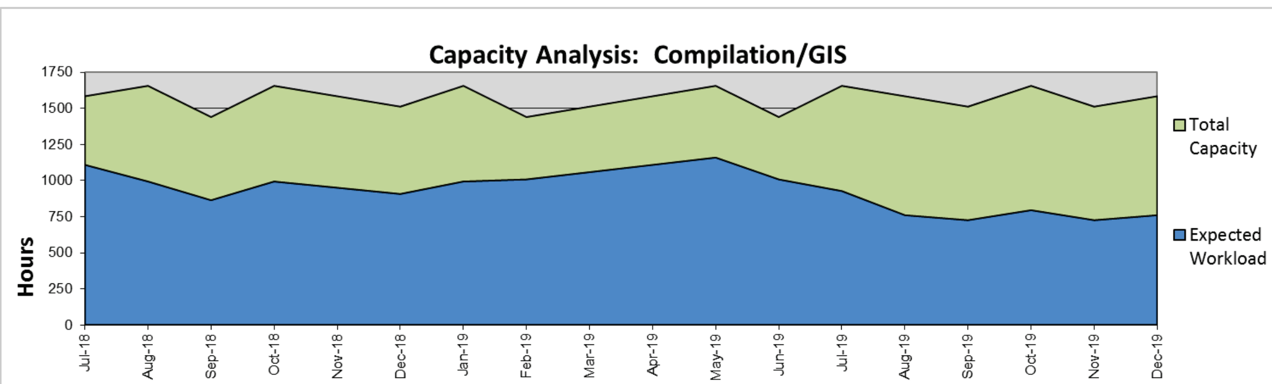




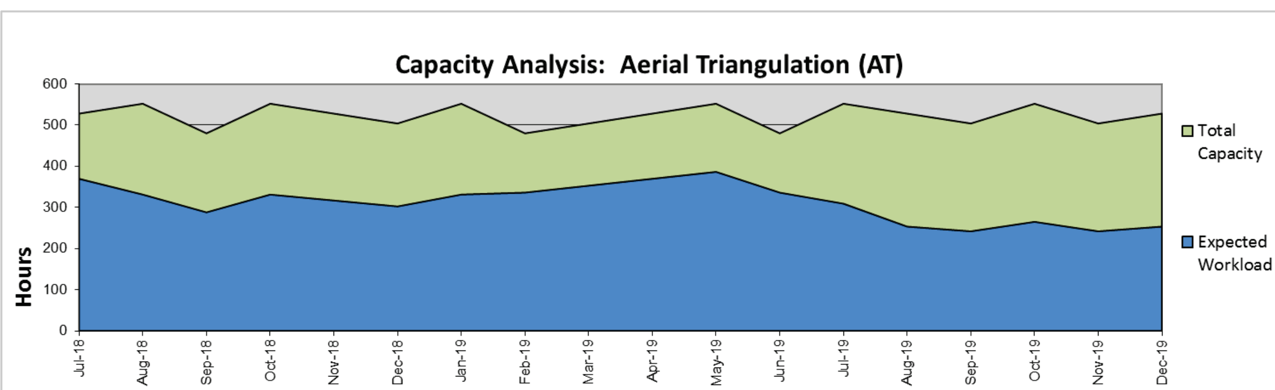
Capacity Analysis: Image Processing
Hours
Total Capacity
Expected Workload
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19



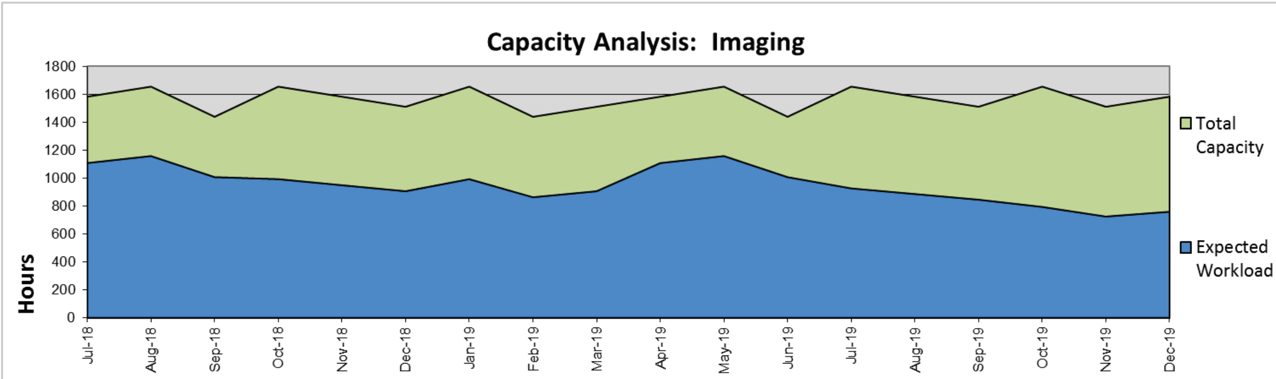
CapacityAnalysis: GPS IMU Processing
Hours
Total Capacity
Expected Workload

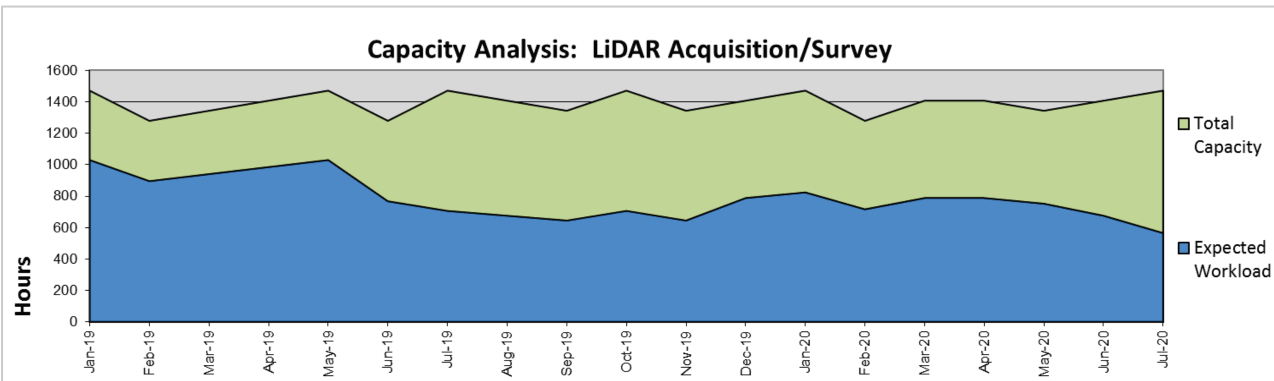


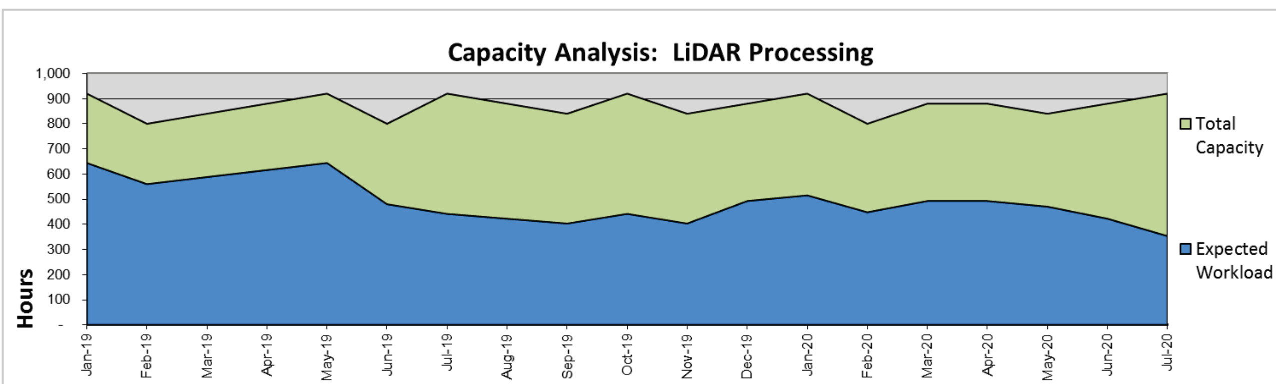
Capacity Analysis: Compilation/GIS
Hours
Total Capacity
Expected Workload



Capacity Analysis: Aerial Triangulation (AT)
Hours
Total Capacity
Expected Workload







Overview of Proposed Schedule

Ms. Marcotte will review the production schedule contained in Sanborn's proposal during the project initiation meeting. This draft schedule, based upon our review of the RFP, may be re-evaluated after the completion of the pilot or prototype project and before the balance of the project is started, depending upon comments received by the COAGA 2019, if they impact the scope of work. It is anticipated that the COAGA 2019 will review the pilot deliverables and provide comments to Sanborn within five days of receipt. If necessary, the resource requirements will be input/revised in the EVM system at both of these milestones before production of the balance of the project commences.

Product Review Cycle

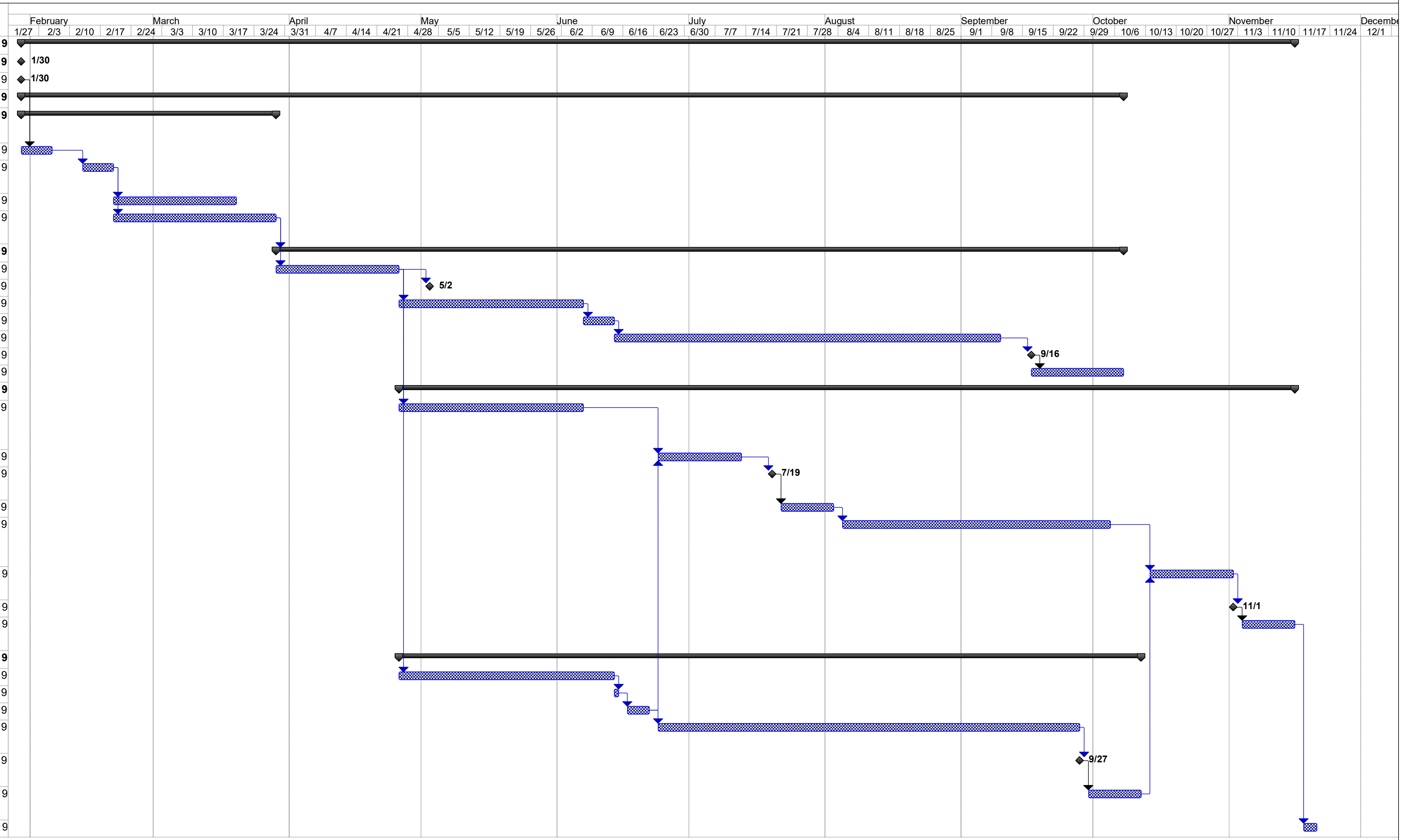
The customer review cycle will be as contained in Sanborn's proposed schedule. COAGA 2019 will be responsible for evaluating and determining the adherence of the deliverables to the acceptance criteria or calculating error rates for the deliverable units within the timeframe described within the proposed schedule. If and to the extent that Sanborn suffers a schedule delay as a result of a delay in the COAGA 2019's review, then Sanborn's schedule will be extended by a period of time equal to the period of delay in the COAGA 2019's review. Sanborn will not be liable in damages or penalties for any such delay.

Proposed Schedule

Sanborn's draft schedule is shown on the following page in a Gantt chart format. If COAGA 2019 has a priority in regards to project areas, Sanborn can accelerate specific project areas or make priority areas after further discussions with COAGA 2019. Sanborn's product schedule includes client-end QA/QC at the end of the project to work through specific items that may be requested by COAGA 2019.

Proposed Schedule
COAGA 2019

ID	Task Name	Start	Finish
1	**COAGA 2019**	**Wed 1/30/19**	**Fri 11/15/19**
2	**Project Execution / Milestones**	**Wed 1/30/19**	**Wed 1/30/19**
3	Project Kickoff Meeting	Wed 1/30/19	Wed 1/30/19
4	**Orthoimagery**	**Wed 1/30/19**	**Mon 10/7/19**
5	**Acquisition of Orthophotography and Optional LiDAR**	**Wed 1/30/19**	**Thu 3/28/19**
6	Acqusition Planning	Wed 1/30/19	Tue 2/5/19
7	Review/approve flight & control plans	Wed 2/13/19	Tue 2/19/19
8	Survey Ground Control	Wed 2/20/19	Tue 3/19/19
9	Acquisition Window (weather permitting)	Wed 2/20/19	Thu 3/28/19
10	**Orthophotography Processing**	**Fri 3/29/19**	**Mon 10/7/19**
11	Aerial Triangulation (AT)	Fri 3/29/19	Thu 4/25/19
12	Deliver Full AT Report	Thu 5/2/19	Thu 5/2/19
13	Ortho Pilot	Fri 4/26/19	Thu 6/6/19
14	COAGA review of pilot area	Fri 6/7/19	Thu 6/13/19
15	Orthophotography processing	Fri 6/14/19	Mon 9/9/19
16	Deliver Orthophotography	Mon 9/16/19	Mon 9/16/19
17	COAGA review of orthoimagery	Tue 9/17/19	Mon 10/7/19
18	**Topographic Data (Optional)**	**Fri 4/26/19**	**Fri 11/15/19**
19	Breaklines, mass points and Hydro-enforced production (Pilot Area)	Fri 4/26/19	Thu 6/6/19
20	Contours (Pilot Area)	Mon 6/24/19	Fri 7/12/19
21	Deliver topographic data (pilot area)	Fri 7/19/19	Fri 7/19/19
22	COAGA review of pilot area	Mon 7/22/19	Fri 8/2/19
23	Draft Breaklines, mass points and Hydro-enforced production (Full production)	Mon 8/5/19	Fri 10/4/19
24	Contours (Full Production incorporating required planimetrics)	Mon 10/14/19	Fri 11/1/19
25	Deliver Full Contour dataset	Fri 11/1/19	Fri 11/1/19
26	COAGA review of full Contour dataset (gdb)	Mon 11/4/19	Fri 11/15/19
27	**Planimetric Update (Optional)**	**Fri 4/26/19**	**Fri 10/11/19**
28	Update planimetric data (Pilot Area)	Fri 4/26/19	Thu 6/13/19
29	Deliver planimetric pilot data	Fri 6/14/19	Fri 6/14/19
30	COAGA review of pilot area	Mon 6/17/19	Fri 6/21/19
31	Update planimetric data (Full production)	Mon 6/24/19	Fri 9/27/19
32	Deliver planimetric geodatabase with metadata	Fri 9/27/19	Fri 9/27/19
33	COAGA review and acceptance of planimetric data	Mon 9/30/19	Fri 10/11/19
34	Project Closeout	Mon 11/18/19	Wed 11/20/19



Date: Wed 12/5/18 | Task | Milestone ◆ | Summary

Final schedule pending execution of contract and acquisition of Aerial Imagery.
Metadata will be delivered at the time of product delivery. Delivery order to be determined at kick-off meeting.

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Financial Schedule

Ms. Marcotte will develop an internal set of financial budgets based upon the input into the EVM system and an invoice and payment schedule that is tied to production and/or terms and conditions in the contract. Ms. Marcotte is responsible for the timely and accurate submission of invoices to the COAGA 2019. The COAGA 2019 is obligated to remit timely and accurate payments in accordance with the terms and conditions of the contract.

Preferred Payment Schedule

Sanborn proposes a milestone invoice schedule in coordination with the delivery schedule:

- 10% upon survey and flight plan approval
- 30% upon acquisition completion
- 20% upon survey report and AT report delivery
- 30% upon initial orthophoto/planimetric/topography delivery by area
- 10% upon final acceptance

Sanborn is willing to negotiate other terms for invoicing if desired.

Experience

Sanborn has always recognized the importance of playing an industry-leading role and providing clients with access to the most progressive solutions available, enabling us to deliver products and services in the most timely and cost-effective manner possible. The company has had a number of important "firsts" in aerial mapping and imaging, including pioneering the use of digital terrain modeling techniques and contour interpolation in 1984, and having the first commercial, proprietary, digital orthophoto imagery production system in the country in 1988. Sanborn purchased its first lidar system in 1998, and began operating digital aerial camera sensors in 2004.

Relevant Experience

Sanborn has a demonstrable track record of success on large, complex orthoimagery, lidar, and planimetric/photogrammetric mapping projects throughout the United States. The company has extensive experience throughout the US and we have mapped millions of square miles of terrain throughout the United States.

Sanborn has had the privilege of working with the COAGA 2015 consortium and produced similar products as required by COAGA 2019. Sanborn also completed similar mapping services for the City of Edmond in 2016 and 2018.

Our work developing and updating COAGA 2015's high accuracy GIS base map and the City of Edmond programs provides us with past experience and familiarity with your program. Our goal in responding to your RFP is to provide convincing evidence that there is no risk to the Sanborn approach, and that COAGA 2019 will benefit from selecting the Sanborn team. We value the

COAGA 2019 consortium and this program and you can be assured that if selected, we will continue to provide an equal or improved level of quality products and customer service.

Sanborn's aircrews are experienced and familiar with the airspace system in the State of Oklahoma and surrounding region, and know how to navigate safely and efficiently within its boundaries. They have the relationships needed to gain access to the sensitive and restricted areas. They know the terrain and local weather patterns, and how to structure mobilizations to take maximum advantage of the limited time window in which to collect leaf-off imagery.

Sanborn has successfully worked with numerous other consortiums to perform similar projects. Our experience includes the State of Virginia's Base Mapping Program, Greater Bridgeport Regional Council, Windham Region Council of Governments, Louisville/Jefferson County Information Consortium, Pikes Peak Geospatial Alliance, and the Houston-Galveston Area Council (HGAC). In addition to coordinating and communicating as needed to complete their imagery, Lidar and mapping projects, Sanborn has hosted informational seminars, developed and delivered in coordination with the governing body, that are held prior to the main flying seasons (and off-seasons as appropriate), to aid in educating and supporting the wide-ranging needs of their constituents.

Subcontractor Experience

Since 2007, Sanborn and Eastdawn have worked together successfully on many projects, including support for AT, DEM/DTM, Orthorectification, Compilation, Lidar and Planimetric feature extraction and update. Representative projects completed by Eastdawn as a member of the Sanborn team are listed below, including several projects provided in the following subsection as references for Sanborn.

- **Gwinnett County, GA.** Lidar, orthophotography and 3D planimetric update.
- **Capitol Region Council of Governments (CRCOG), CT.** Lidar and orthophotography.
- **Arkansas Statewide Orthoimagery Program, AR.** Orthophotography.
- **Capital Area Governments (CAPCOG), TX**. Stereo-compilation planimetric features.
- **Moreno Valley, CA**. Stereo-compilation planimetric features.
- **Commonwealth of Virginia (VGIN), VA**. Stereo-Compilation updates and orthoimagery seamlining.
- **Cedar Rapids AT & Ortho Project, IA**. Aero-triangluation of 12,831 images in one single block suitable to produce 1":50' scale orthoimagery. Produced full color 4-band, 8-bit, 1":50' orthos with 0.25-foot ground sample distance utilizing bare earth lidar data provided by the client.
- **WGP Butler Lateral-Corridor Mapping Project, PA**. Compilation and cartographic editing of planimetric data and generation of 2-foot contours for a corridor in Pennsylvania at a scale of 100' with an accuracy to meet NMAS specifications. The area of interest was approximately 83.179 miles in length by 1.00653 miles in width.
- **Lewis & Clark Project, MT**. Aero-Triangulation, Lidar DEM Update, Orthos, building footprints, update of transportation features and contours within a 319 sq mile area of Lewis and Clark Counties in Montana.

Comparable Customer References

Sanborn has a demonstrable track record of success on large, complex orthoimagery, lidar and photogrammetric mapping projects throughout the United States. Representative projects that demonstrate Sanborn's ability to deliver projects of this size, scope, and complexity are provided on the following pages, including contact information.

Reference:
GIS Base Map Update, Gwinnett County, GA

The Gwinnett County, Georgia, project is a large GIS program that includes Lidar, digital camera acquisition, topographic and planimetric mapping, and 6-inch resolution orthoimagery. Sanborn has successfully performed this ongoing program for approximately fifteen years, with 100 percent client satisfaction with quality of all products, including enhanced radiometry of the orthoimagery.

Contact Name	**Eric Britt** ITS Manager
Phone/Fax	(770) 822-8032 / (770) 822-8014
Email	eric.britt@gwinnettcounty.com
Customer Name	**Gwinnett County, Georgia**
Address	75 Langley Drive Lawrenceville, GA 30045
Project Term	February 1999—Ongoing (January 2019, with 3 additional option years)
Project Value	$ 6,500,000 ($ 2,942,690 since 2011)
Project Area	458 square miles

Project Background

Gwinnett County has updated and upgraded their customer service capabilities and applications on a continuing basis since the initiation of their GIS in the 1990's. Gwinnett County uses this information for planning and zoning, property records, parks, transportation planning, traffic and accident analysis, elections administration, public safety (police and fire), public utilities (water and sewer), economic development, and environmental and natural resource management. The update and enhancement of their GIS includes new orthoimagery, Lidar, topography and base map revisions on a yearly basis. Gwinnett County originally selected Sanborn (previously ASI) in 1999 to deliver digital orthophoto imagery, planimetric, topographic, and cadastral mapping. The contract has been renewed numerous times and is now in effect through 2018, as a direct result of Sanborn's timely, on-budget, and high quality deliveries over the years.

Project Scope

- **Update Mapping:** Sanborn has been updating the mapping for Gwinnett County on a yearly basis since 1999. Each year the mapping update includes new imagery and Lidar acquisition. A comprehensive update of the planimetric/topographic data is performed in two phases, and includes the Lidar derivative products in Phase 2.
- **Phase 1:** The first phase of the project requires the update of impervious surfaces and digital orthoimagery for the entire County *within two to three months of flight.*
- **Phase 2**: The second phase of the project requires additional the balance of the planimetric feature update, topographic updates, 2-foot contour update and Lidar derivative products.

The resultant products meet or exceed ASPRS Class 1 Accuracy specifications for Lidar products, planimetric, 2-foot contours and digital orthoimagery at 1"=100' scale map accuracy. The Lidar mission is flown yearly at an average of 1.4 Nominal Point Spacing (NPS) to be used for both digital orthoimagery production and development of a new classified point cloud, intensity images, and Digital Elevation Model (DEM) surface throughout the County. The Lidar DEM data are edited concurrently with the planimetric data, to support quality 6-inch digital orthoimagery and finalized for NSSDA quality products.

Previous Work for Gwinnett: Sanborn has been performing photogrammetric work for Gwinnett County since 1999.

- **Cadastral digital data conversion**—Cadastral maps covering over 148,000 parcels were digitally converted and formatted. Deliverables included digital data formatted into 53 database layers, final plots, and linked attribute files.
- **Overview of Products**—Countywide digital camera aerial imagery, ground control survey, aerial triangulation, 6-inch orthoimagery, comprehensive planimetric update, Lidar acquisition/DEM generation and update of 2-foot contours.

Reference: Capitol Region Council of Governments (CRCOG) Connecticut Statewide Orthoimagery, Lidar & GIS Data Acquisition Program

CRCOG, acting on behalf of public agencies in the State of Connecticut (State), was seeking high-resolution orthoimagery, high-density Lidar, and peripheral data for the entire state. CRCOG also wanted to have a contract vehicle that would allow public agencies to procure a comprehensive range of aerial imagery and Lidar derivative data products to meet their individual business requirements. Sanborn was selected on a competitive basis and awarded a contract to provide the required products and services.

Contact Name	**Erik D. Snowden** IT/GIS Coordinator
Phone	(860) 522-2217 x217
Email	**esnowden@crcog.org**
Customer Name	Capitol Region Council of Governments (CRCOG)
Address	241 Main Street Hartford, CT 06106
Project Term	March, 2016 – May, 2017
Project Value	$1,776,089.15 (Primary) $1,947,556.03 (Optional Buy-ups)
Project Area	5,543 square miles

Project Background

Excepting a few procurements at the regional level, agencies within the State of Connecticut, and notably, the 169 towns, had historically acted on an individual basis to procure aerial imagery, Lidar, and related data. This made inefficient use of their funding, something the State particularly noted with respect to the grant funding it provided for many of these small, individual projects. The decision was made that the State would provide funding through a Regional Performance Incentive Grant from the Connecticut Office of Policy Management to procure orthoimagery, Lidar, and a number of key derivative data products for the entire state, and distribute these data to any public agency that wanted them for no cost. CRCOG was elected to be the procuring and managing agency for this program. The core data products included 3-inch resolution 4-band RGBN orthoimagery; USGS Lidar Base Specification Version 1.2 compliant Quality Level 2 Lidar with all mandated deliverables, and 1-foot contours, all covering the entire state.

Project Scope

Primary data acquisition was performed in March and April of 2016. Sanborn supported the State's disadvantaged business assistance program by working with a small, locally based land surveying company to set all of the required targeted ground control, checkpoints, and calibration points for the 5,200-square-mile project. Airborne GPS and IMU technologies were used to collect precise sensor position and orientation information. Digital analytical aerotriangulation was performed to verify and enhance the imagery position and orientation solution.

Imagery had to be collected not only under snow-free, leaf-off conditions and clear skies; contractual requirements called for photography along the shoreline to be tide coordinated as well. Over 42,500 images were acquired within a 5-week time frame, over 6,000 of which were collected at mean low tide along the shoreline. Imagery collection was constrained to higher than normal sun angle requirements due to the number of high buildings and building density in many parts of the state, in order to minimize the detrimental effects of shadows. Sanborn also collected imagery at very high overlaps in urban cores in order to minimize the lean of tall buildings, bridges, and interchanges.

Lidar acquisition also had to be tide coordinated, and collected as nearly as possible to the imagery in order to minimize temporal differences in the two data sets. The Lidar aircraft were deployed with multiple crews in order to enable around-the-clock collection of data in order to complete acquisition in the minimum possible time. All Lidar was collected within a 4-week time frame. The raw Lidar, collected at two (2) points per square meter Aggregate Nominal Pulse Density (ANPD), was post-processed by Sanborn's Lidar technicians to create a calibrated Lidar data set. Classification was performed in accordance with the USGS specifications, and a hydro-flattened, breakline-enhanced bare-earth digital terrain model was created. One-foot contours were generated. Primary Lidar deliverables included raw and classified point clouds, bare earth DEM, hydro-flattening breaklines, contours, and intensity images. Deliverable Lidar data formats included LAS v1.4, ASCII, Esri Geodatabase, Esri Raster, and GeoTIFF.

The Lidar-generated DTM was used to orthorectify the aerial imagery. A 4-band, 8-bit per channel RGB/NIR orthoimagery data set was produced at 3-inch resolution. Orthoimagery tiles in a 1,250-foot x 1,250-foot array were delivered in GeoTIFF and MrSID formats. MrSID mosaics were also produced for each of the 169 towns.

Sanborn also offered a comprehensive program for optional buy-up products and services. Agencies have procured $1,947,556.03 worth of true orthophotography, QL-1 enhanced Lidar, oblique imagery, planimetric mapping, and 3D buildings.

As part of this program, program, Sanborn completed a highly complex $674,000 planimetric mapping project for Western Connecticut Council of Governments, or WestCOG (Contact: Dr. Carl Zimmerman, Tel. 203-965-4976, czimmerman@westcog.org). Sanborn also completed a $957,000 geodatabase design and planimetric mapping project for Southern Connecticut Gas Company (Contact: Ms. Rebecca Lenk, Tel. 203-795-7762, RLenk@soconngas.com), as well as a $119,000 geodatabase design and planimetric mapping project for The Connecticut Water Company (Contact: Dan Goodrich, 860-664-6065, DGoodrich@ctwater.com). Many other smaller planimetric mapping projects were completed as well.

Sanborn fulfilled all program management responsibilities, thoroughly quality-controlled all data sets, and coordinated with CRCOG GIS staff and their independent third-party QC vendor to process minor corrections. A complete set of FGDC-compliant metadata and comprehensive project documentation was delivered with the data. Sanborn also worked with staff from the University of Connecticut to coordinate their hosting and deployment of all data. Accuracy requirements for the program are tabulated below.

Horizontal Accuracy Requirements – Orthoimagery *Per ASPRS Positional Accuracy Standards for Digital Geospatial Data (V1.0 - Nov. 2014)*			
Horizontal Accuracy Class	**RMSEx and RMSEy (cm)**	**RMSEr (cm)**	**Horizontal Accuracy at 95% Confidence Level (cm)**
15 cm	≤15	≤21.2	≤36.7

USGS QL2 Lidar Accuracy Requirements	
Absolute Accuracy	
RMSEZ (non-vegetated) (cm)	≤ 10.0
NVA at 95-percent confidence level (cm)	≤ 19.6
VVA at 95-percent confidence level (cm)	≤ 29.4

Reference:
Louisville/Jefferson County Information Consortium

Contact Name	**Curt Bynum** LOJIC GIS Coordinator
Phone / Fax	(502) 540-6121 / (502) 540-6499
Email	curt.bynum@lojic.org
Customer Name	**Louisville/Jefferson County Information Consortium (LOJIC)**
Address	700 West Liberty Street Louisville, KY 40203
Project Term	March 2012—September 2013
Project Value	$458,000
Project Area	900 square miles

Louisville/Jefferson County Information Consortium (LOJIC) represents a cooperative effort on the part of Louisville Metro Government, the Jefferson County Property Valuation Administrator, Louisville Water Company and the Metropolitan Sewer District to build and maintain a comprehensive enterprise geospatial information system (GIS) for the region. The LOJIC GIS has been fully operational for nearly 25 years and contains myriad digital map layers and other spatial databases. It was designed to support the cartographic and applications needs of hundreds of users from local government and utility agencies throughout the region. Sanborn has worked with LOJIC on several projects since the late 1980's.

Project Scope

This project included the Spring 2012 acquisition of 16-bit Red, Green, Blue, and NIR digital aerial imagery, and the generation of high quality 0.5-foot digital orthoimagery for delivery in GeoTIFF format and MrSID files for each of the three counties. The imagery acquisition was supported by airborne GPS (AGPS) and ground control to support 1"=100' scale planimetric mapping. A robust analytical triangulation was performed to support both the orthoimagery generation and planimetric update.

Lidar was acquired at a Nominal Point Spacing (NPS) of 1.4 meters, processed and classified to include bare earth, buildings, water, and vegetation classifications. Hydro-flattening of the bare earth Lidar dataset was performed for streams with a minimum width of 50 feet and water bodes with a minimum size of 1 acre. All breaklines developed were provided as parallel elevations with downstream flow and delivered as Esri feature classes. Final deliveries included DEM, DTM and DSM files.

All portions of Jefferson, Oldham and Bullitt Counties were updated using high accuracy analytical stereo plotters for new, updated and deleted features. New features were attributed with the date field. Our subcontractor SDIMaps, Inc., assisted with the planimetric update.

Technical Specifications	
Lidar	▪ 1.4 NPS, 15 cm RMSE
Aerial Photography	▪ 0.5-foot Digital Mapping Camera (DMC) Imagery
Planimetric Update	▪ ASPRS Class 1 standards for mapping at 1:1200 (1"=100') scale
Ground Control Survey	▪ To support Class 1 mapping standards for 1"=100' map scale
Topographic Mapping	▪ DTM generated from the Lidar to support 2-foot contour interpolation
Orthophotography	▪ 0.5-foot orthorectified 4-band 80-bit R, G, B, NIR

Reference:
Arkansas Statewide Orthoimagery Program

The project includes the acquisition and processing of new 4-band (Red, Green, Blue, Near-Infrared) of orthoimagery throughout the State of Arkansas at 1-foot (30cm) resolution (approximately 54,000 square miles of coverage). In the first year of the contract (2017), the State opted to obtain an additional 3,498 square miles of imagery upgraded to 6-inch (15cm) resolution for select urbanized areas.

Contact Name	**Shelby D Johnson** Geographic Information Officer
Phone	(501) 682-2943
Email	shelby.johnson@arkansas.gov
Customer Name	State of Arkansas
Address	Arkansas GIS Office 1 Capitol Mall Ste 6D Little Rock, AR 72201
Project Term	January 2017 – January 2018, plus 6 optional years
Project Value	~ $1.27 M
Project Area	54,000 square miles

Project Background

In the fall of 2016 the Office of State Procurement (OSP) on behalf of the Arkansas Geographic Information Systems (GIS) office issued a Request for Proposal to obtain a qualified vendor to provide aerial orthoimagery services. Sanborn was evaluated as the most qualified and experienced responder and entered into a one year contract with six (6) optional one year terms to provide mapping services throughout the State.

Project Scope

Sanborn is responsible for all aspects of new orthoimagery production, including:

- 4-band (Red, Green, Blue, Near-Infrared) 8-bit per channel imagery acquisition
- Imagery acquisition supported by ground control survey and Airborne GPS
- Aerial Triangulation
- Update of existing or development of a new Digital Elevation Model (DEM)
- Imagery rectification
- Mosaicking and final orthoimagery tile extractions

Sanborn's team supplied five aircraft and sensors, which enabled the Sanborn team to successfully acquire all imagery in one flying season, despite the fact that the State experienced an early spring in 2017 and leaf out conditions began in late February/early March. UltraCam Eagle imagery sensors were utilized to acquire the imagery at altitudes to support development of 1-foot (30 cm) resolution imagery statewide and 6-inch (15 cm) orthoimagery for select urban areas (3,498 square miles). All products for 2017 were completed and delivered to the state by December 31, 2017.

Summary of Deliverables	
Deliverable	**Description**
Field Survey Report	Sanborn will submit a comprehensive survey report documenting the survey in PDF format, and an Esri Geodatabase file with all of the coordinate data.
Flight Plans	Sanborn delivered the final flight line map/photo index with photo centers in Esri Geodatabase and Adobe PDF formats.
Aerial Triangulation	Sanborn provided a fully-indexed AT report that provides a narrative description of all aspects of the AT phase, tabular information for ground control and check point results, and appendices including full AT solution printouts. An Adobe .PDF version of the report and a Microsoft Excel file with the point coordinates was also provided as well.
Raw Imagery (Quick Look) WMS	Sanborn provided a copy of the raw geo-referenced imagery via a WMS within 14 days following the acquisition.
Digital Orthophotography	Sanborn provided a copy of all orthoimagery tiles (56,010 sq. miles of 1-foot, and 3,498 sq. miles of 6-inch) at the desired spatial resolution of 1-foot in .TIFF/.TIFW format, and composition MrSID compressed format. Radiometry was 4-band, 8-bit per channel RGB.
MrSID Mosaics	MrSID mosaics were provided for counties or municipalities in .SID/.SDW format with 20:1 compression. Radiometry was 4-band, 8-bit per channel RGB/NIR.

Summary of Deliverables	
Deliverable	**Description**
DEM	Sanborn provided a copy of the updated digital elevation model created for use in orthorectification.
Tile Report	Sanborn submitted a final tile report following the imagery acquisition phase.
GeoServe	The orthoimagery was initially provided in Sanborn's web-based OSP review software.
WMS/WMTS	In addition to Quicklook and Geoserve, Sanborn provided additional web mapping services.
Metadata	Sanborn provided FGDC compliant metadata for the project in the format of the OSP's choosing.
Project Documentation	Sanborn provided a copy of all required project documentation including reports regarding aircraft and camera operation, calibration reports, QA/QC reports, and management & administrative documents.
Deliverable Media	Final data was delivered on USB External Hard Drives. DVD 2.0, 4.7 GB single sided (4.3 GB usable) disks or FTP download was also available for interim deliverables, such as pilot data sets.

Customer Quote:

The early access and expedited imagery delivery was a major benefit for the State's Geographic Information System base map," says Shelby D. Johnson, Geographic Information Officer from the Arkansas GIS Office. "We were able to provide imagery data quicker than previous projects while dramatically improving the resolution and quality of the imagery for many areas. The new data provides significant value to our constituents. Our ability to quickly disseminate this data to many of our rural 9-1-1 centers in the State will enable them to put it to use for public safety faster. It's a springboard for them on the steps toward next-generation 9-1-1 capability.

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Reference:
Pikes Peak Geospatial Alliance, Colorado

Contact Name	**Mike Herrmann,** Manager, Asset Management/Geospatial Technologies
Phone / Fax	(719) 668-8369 / (719) 668-5329
Email	MHerrmann@csu.org
Customer Name	**Pikes Peak Geospatial Alliance (PPGA)**
Address	111 S. Cascade Avenue Colorado Springs, CO 80903
Project Term	March 2007 – December 2008 April 2009 – April 2010 March 2011 – March 2016 February 2016 – January 2018 (plus 3 option years)
Project Value	\$456,458 (2007) \$149,543 (2009) \$761,305 (2011) \$223,857 (2016)
Project Area	~ 2,500 square miles

Sanborn was selected by the Pikes Peak Geospatial Alliance (PPGA) in the Spring of 2007 to provide digital orthoimagery covering several jurisdictions. The PPGA consists of multiple agencies including the City of Colorado Springs, El Paso County, Teller County, E911, and four military installations. Since 2008, Sanborn has completed Lidar flights within the Colorado Springs region for Colorado Springs Utilities (CSU) and the Pikes Peak Geospatial Alliance. Sanborn had an orthoimagery and Lidar contract awarded in 2011, with three option years exercised. Sanborn's most current contract was awarded in February, 2016, and is scheduled to be completed in January, 2018, followed by an additional 3 option years.

Project Scope

Sanborn was selected by the PPGA in the Spring of 2007 to provide 2,890 square miles of digital orthoimagery, covering multiple jurisdictions. The PPGA contracted with Sanborn again in 2009 to provide 2,226 square miles of 1-foot orthoimagery over Colorado Springs, El Paso County and Woodland Park in Teller County. The imagery was acquired in summer of 2010 and the project was completed on schedule in spring 2011. In 2014, Sanborn was again given a task order by PPGA to collect 2,233 square miles of 0.5- foot and 1-foot imagery in El Paso County and the City of Colorado Springs.

The scope of work in the most recent program (2016) included the utilization of digital camera technology for 391 square miles of 0.5-foot resolution imagery within the City of Colorado Springs, and 2,400 square miles of 1-foot resolution imagery within El Paso County and Teller County. The terrain variance extends from 5,000 feet above sea level to over 14,000 feet in elevation. Sanborn delivered 4-band orthoimagery and updated digital elevation models.

Sanborn has completed additional Lidar, digital orthoimagery and DEM update projects, including the following, for the PPGA:

- **UAV mapping of transmission corridor:** In 2014, PPGA, through partner Colorado Springs Utilities, selected Sanborn to perform UAV imagery collection and processing of imagery along a critical route within the City of Colorado Springs. The program took 3 days to collect and the data was delivered within several days of acquisition.
- **Pikes Peak Geospatial Alliance**: Sanborn collected 2,000 square miles of Lidar and imagery data of El Paso County in 2011. The project area contains terrain variances of over 8,000 feet. Further, breakline hydro enforcement was required for specific drainages throughout the County which exceed USGS specifications. The Lidar data was collected at a density of 1.4-meters and supported a 15-cm RMSE accuracy. Sanborn produced derived products that included 2-foot contour lines, arcGRID DEMs and final DTMs with breaklines for hydro enforcement. Sanborn collected 20 check points and produced a NSSDA report for accuracy assessment.
- **Monument Creek Waldo Fire Emergency Response**: After the Waldo Canyon Fire in 2012, erosion exposed a major pipeline carrying water from Rampart Reservoir to the City. Sanborn collected 8 pts/m^2 density Lidar for CSU to assess the damage and calculate the metric ton of material needed to fill the exposed area. Data was captured and delivered within a 1-week timeframe.
- **Southern Delivery System Pipeline Analysis**: In 2012 Sanborn completed a corridor of Lidar collection. The data was used to assess change to the terrain from pre- to post-pipeline status. Data accuracy and density supported 1-foot contours and a 9.25cm RMSE. Data was captured and delivered within a 2-week schedule.

- **Colorado Springs 3D Model**: Sanborn was commissioned to complete two independent Lidar acquisitions over the urban area of Colorado Springs for 3D modeling purposes. The Lidar flight was completed with multiple perpendicular flight lines allowing for the elimination of Lidar "shadows" caused by buildings. The second Lidar acquisition was completed at the top of Hoosier Pass for portions of Park and Summit County. Careful flight planning, ground control selection, and acquisition procedures were needed to ensure that the data continued no voids, that the density of points allowed for 2-foot and 4-foot terrain modeling, and that the overall data met accuracy expectations.

Section 4 – Exceptions to the RFP

Exceptions

The Sanborn Team will adhere to all specifications for map/feature accuracy, quality, adherence to graphic standards, attribution, etc. as defined by COAGA 2019 and specified in your RFP.

Sanborn understands that many of the basic terms and conditions in the RFP are based upon statutory or regulatory requirements and are not subject to negotiation. Sanborn notes that certain terms and conditions may or may not be applicable to this procurement, or may require adjustment based on the specifics of this procurement; and, reserves the right to discuss and negotiate these terms and conditions during the contract negotiation. Specifically, Sanborn would like to discuss the following items:

- Express terms for payment upon cancellation and mutual termination rights
  - Sanborn would like to include language on express terms for payment upon cancellation to ensure payment for services performed and those in process at the time of termination along with mutually beneficial termination rights.
  - Sanborn proposes the following language for consideration:
    - This Agreement shall remain in effect from the date contained herein until terminated by either party by giving thirty (30) days' written notice to the other party. If terminating for any reason other than convenience or delay or default in payment obligations, the terminating party shall provide the other party at least thirty (30) days to cure, or to submit an acceptable plan to cure, prior to the effective date of such termination. Upon the date so specified, Sanborn shall immediately terminate all activities on behalf of COAGA 2019. Notwithstanding any such termination, COAGA 2019 shall in no event be released from its obligation to pay Sanborn for all Services performed and those in process at the time of such termination, and Deliverables delivered prior to such termination.
- Ownership/license transfer upon final payment
  - Sanborn would like to include language on ownership transfer rights upon final payment to ensure payment for services performed.
  - Sanborn proposes the following language for consideration:
    - Sanborn shall be the sole and exclusive owner of all right, title and interest in and to the work materials and Deliverables until such time as Sanborn has received full and final payment of all outstanding invoices with respect to the performance of the Services and delivery of the Deliverables hereunder. At such time as payment in full has been rendered to Sanborn, COAGA 2019 shall have such rights, title, and interest in and to the Deliverables.
- Limited Liability
  - Sanborn would like to include additional liability language.
  - Sanborn proposes the following language for consideration:

- Notwithstanding any other provision of this Agreement, neither party will be liable to the other for any punitive, indirect, special, consequential or incidental damages whatsoever. Sanborn's maximum aggregate liability to COAGA 2019 shall be limited to the aggregate dollar value of fees paid to Sanborn by COAGA 2019 pursuant to the terms hereof.

- Provision for force majeure
  - The RFP has a limited Force Majeure but Sanborn would like to propose the use of a more comprehensive Force Majeure.
  - Sanborn proposes the following language for consideration:
    - Neither party shall be liable in damages or have the right to terminate the Contract resulting from this RFP and Proposal for any delay or default in performing (with the exception of payment obligations) if such delay or default is caused by events of Force Majeure. Force Majeure shall mean any events or actions beyond the reasonable control of either COAGA 2019 or Sanborn preventing or delaying the execution of or compliance with any of the terms and conditions contained in the Proposal and/or Contract resulting from this RFP and Proposal, including but not limited to strikes, lockouts, labor shortages, actions or inactions of independent subcontractors and suppliers, power shortages, wars, acts of God, and governmental regulations, including the restrictions imposed by air traffic control personnel with authority over airspace required for flight operations, restricting normal operations, weather or atmospheric conditions that are not conducive for the collection of aerial imagery or terrain data in a manner that is necessary to meet or exceed the requirements of any deliverable and inability of the COAGA 2019 to provide any specified sources in a timely manner. Sources shall mean all information and/or materials as may be defined in the Proposal required to be provided by COAGA 2019 to Sanborn for the performance of the services. If and to the extent that Sanborn suffers a delay as a result of an event of Force Majeure, then it shall be entitled to a delivery schedule extension by a period of time equal to the period of interruption caused by the Force Majeure event.
- Warranty Disclaimer
  - Sanborn proposes to include a warranty disclaimer to ensure warranties are not made by either party except for the express warranties made or referenced in this proposal or contract resulting from this RFP.
    - Except for the express warranties made or referenced in this proposal or contract resulting from this RFP and proposal, neither party makes any warranties, express or implied, including without limitation any implied warranty of merchantability or of fitness for a particular purpose as to any items or services provided under the contract resulting from this RFP and proposal.

Sanborn is confident that a mutually acceptable Contract will be negotiated upon selection that is based upon and reflects the final project specifications, deliverables, schedule, and fees.

Subcontractor Terms and Conditions

Sanborn understands that any and all subcontractors are required to comply with all applicable provisions from the Contract, including such items as 4.2 Insurance. However, Sanborn is proposing the use of an off-shore subcontractor as a better value to COAGA 2019. As an off-shore entity, they are not subject to US laws and regulations and may not be able to comply with the requirements as a domestic company would. Please note that Sanborn qualifies all subcontractors using a rigorous and formal process, and it is Sanborn's policy to review, verify, and be responsible for all work performed by any subcontractor it utilizes.

Omissions

Sanborn meets or exceeds all requirements of the COAGA 2019 program, with no omissions.

Alternatives

We offer the following no-cost options that we feel are advantageous to COAGA 2019:

4th NIR band: Our software enables Sanborn to orthorectify all four bands simultaneously, so there is no upcharge over collection and processing of 3-band imagery to deliver a 4-band orthorectified imagery product, providing added value to COAGA 2019. This band is very valuable for a myriad of applications, such as land cover classification, storm water mapping, etc. Each COAGA 2019 member can select this option, as desired.

Quick View Imagery: Sanborn will provide COAGA 2019 with early access to the georeferenced imagery ***within 14 days of being flown***, via a URL. This imagery can be viewed in ArcGIS Desktop or other GIS programs which support OGC web map services.

Web-Based Client QC (GeoServe): For the orthophotography review, Sanborn will provide an optional, no-cost web-based quality control application for COAGA 2019, to allow multiple users to review the orthophotography and provide comments instantly back to Sanborn. Data is served from a central data server at Sanborn to the customer-side computer and uses a mapping interface from within a standard web browser, for the COAGA 2019 participants to review the orthophotography. The tool accelerates the review process and expedites final product acceptance and delivery.

Section 5 – Additional Pertinent Information

Sanborn has thoroughly reviewed your RFP and associated documents and found them to be clear and concise, and is not aware of any omissions from the RFP. Sanborn has successfully completed dozens of projects that are similar in size, scope, and required deliverables to your program, and mapped millions of square miles of imagery and/or topography. We can meet or exceed all specifications, and have responded to all requirements.

All descriptions of alternative or optional functionality that Sanborn has deemed to be potentially advantageous or beneficial to COAGA 2019 have been presented in Section 2, Project Approach, and in Section 4, Alternatives, of this proposal response.

These include three (3) no-cost options: (1) each participant to decide if they want delivery of the 4th band (NIR) as part of the orthoimagery layer, at no additional cost; (2) quick view of imagery within 14-days; and (3) online editing of the orthoimagery for each participant.

Section 6 – Fee Proposal

Sanborn has prepared the attached firm fixed cost forms based upon our understanding of the RFP. The proposed pricing covers all necessary work, materials, supplies, data preparation, entry, translation and quality control, etc. Reproduction, travel and other direct and indirect costs are also included. Please note that Sanborn considers our pricing information to be confidential and proprietary, as it is reflective and manifest of confidential and proprietary technologies, methods and procedures.

As always, Sanborn is willing to negotiate the final project scope of work and related fees.

hard copy products procured, created, or generated in the development of the document database. These records, data, programs, and other materials shall be surrendered to participating agencies upon completion or termination of the project.

Respondents, the Contractor or subcontractor shall not make any claim or right of ownership under patent or copyright law to any of the materials, data, or programs created specifically for this project. The Contractor may not reveal, share, or sell any of these products without written permission of the agency or agencies for which it was written. These terms and conditions exclude any pre-existing conversion software the Contractor may have developed or commercial software acquired prior to beginning work on this project.

Section 10: Cost Proposal Forms

The COAGA 2019 is seeking firm fixed prices for the performance and delivery of digital orthoimagery and flight plan map. Prices shall cover all necessary work, materials, supplies, data preparation, entry, translation and quality control, etc. Reproduction, travel and other direct and indirect costs should also be included.

It is the responsibility of the Respondent to verify any count information used in estimating the cost of conversion. These estimates are based on the most current information available.

The following firm fixed cost worksheet should be filled out as a minimum. ***The worksheet must be accompanied by the non-collusion affidavits found in Appendix I: Forms***.

10.1 Firm Fixed Unit Costs: Appendix B – Digital Color Orthoimagery (TIFF)

City of Edmond (127 miles @ 3")	$250.00/sq mile
City of Del City (8 miles @ 3")	$250.00/sq mile
City of Midwest City (42.43 miles @ 3")	$250.00/sq mile
City of Moore (21.9 miles @ 6")	$125.00/ sq mile
City of Norman (164 miles @ 6" and 92 miles @3")	6-inch: $125.00/sq mile & 3-inch: $250.00/sq mile
Canadian County (ACOG) (approx.. 897 miles @ 6")	$75.00 /sq mile
OR (897 miles @ 12")	$30.00/sq mile

Optional mosaic products:

1. MrSID and JP2000 of City of Edmond	Included
2. MrSID and JP2000 of City of Del City	Included
3. MrSID and JP2000 of City of Midwest City	Included
4. MrSID and JP2000 of City of Moore	Included
5. MrSID and JP2000 of City of Norman	Included
6. MrSID and JP2000 of Canadian County - ACOG	Included
7. MrSID and JP2000 of Entire Project Area - ACOG	Included

10.2 Optional Mapping Deliverables

City of Edmond

Planimetric Change Detection & Collection - Pilot Study Area Cost	$3,141.60
Planimetric Change Detection & Collection - Remainder of the City	$28,274.39
LiDAR Collection and interpolation of the HE-DTM into 1 foot Contours - Pilot Area	$2,724.53
LiDAR Collection and interpolation of the HE-DTM into 1 foot Contours - Remainder of the City	$24,520.78

City of Norman - See Appendix G for Collection Areas and Features

Planimetric Change Detection & Collection 1" = 50' - Pilot Study Area Cost	$2,394.89
Planimetric Change Detection & Collection 1" = 100' - Pilot Study Area Cost	$1,196.00
Planimetric Change Detection & Collection 1" = 50' - Remainder of the Collection Area	$21,554.03
Planimetric Change Detection & Collection 1" = 100' - Remainder of the Collection Area	$10,764.00
LiDAR Collection and interpolation of the HE-DTM into 1 foot Contours - Pilot Area	$2,188.21
LiDAR Collection and interpolation of the HE-DTM into 2 feet Contours - Pilot Area	$2,515.76
LiDAR Collection and interpolation of the HE-DTM into 1 foot Contours - Remainder of the Collection Area	$19,693.85
LiDAR Collection and interpolation of the HE-DTM into 2 feet Contours - Remainder of the Collection Area	$22,641.87
FEMA compliant Vertical Accuracy Report (60 check points)	$14,355.00

In addition, the Respondent may propose alternative pricing methods per Section 8.13. The participating agencies of COAGA 2019 reserve the right to limit the scope of the project.

Appendix I: Forms

As required by the RFP, Sanborn's completed and executed Non-collusion Affidavit forms are provided on the following pages.

AFFIDAVIT OF NON-COLLUSION

City of Edmond, OK

STATE OF Colorado)

COUNTY OF El Paso)ss

John R. Copple, of lawful age, being first duly sworn, on oath says, that (s)he is the agent authorized by the bidder to submit the attached bid. Affidavit further states that the bidder has not been a party to any collusion among bidders in restraint to freedom of competition by agreement to bid at a fixed price or to refrain from bidding; or with any city official or employee as to quantity, quality, or price in the prospective contract, or any other terms of prospective contract; or in any discussion between bidders and any city official concerning exchange of money or other thing of value for special consideration in the letting of a contract; that the bidder/contractor has not paid, given or donated or agreed to pay, give or donate to any officer or employee of the City of Edmond, Oklahoma any money or other thing of value, either directly or indirectly, in the procuring of the award of a contract pursuant to this bid.

The Sanborn Map Company, Inc.
Bidder

By: [signature]

Subscribed and sworn to before me on this 5th day of December, 20 18

[signature]

My Commission Expires 30 June 2021

EMMA S NORTHUP
Notary Public
State of Colorado
Notary ID # 20094020968
My Commission Expires 06-30-2021

AFFIDAVIT OF NON-COLLUSION

City of Del City, OK

STATE OF Colorado)

COUNTY OF El Paso)ss

John R. Copple, of lawful age, being first duly sworn, on oath says, that (s)he is the agent authorized by the bidder to submit the attached bid. Affidavit further states that the bidder has not been a party to any collusion among bidders in restraint to freedom of competition by agreement to bid at a fixed price or to refrain from bidding; or with any city official or employee as to quantity, quality, or price in the prospective contract, or any other terms of prospective contract; or in any discussion between bidders and any city official concerning exchange of money or other thing of value for special consideration in the letting of a contract; that the bidder/contractor has not paid, given or donated or agreed to pay, give or donate to any officer or employee of the City of Del City, Oklahoma any money or other thing of value, either directly or indirectly, in the procuring of the award of a contract pursuant to this bid.

The Sanborn Map Company, Inc.
Bidder

By: [signature]

Subscribed and sworn to before me on this 5th day of December, 2018

[signature]

My Commission Expires 30 June 2021

EMMA S NORTHUP
Notary Public
State of Colorado
Notary ID # 20094020968
My Commission Expires 06-30-2021

AFFIDAVIT OF NON-COLLUSION

City of Midwest City, OK

STATE OF Colorado)

COUNTY OF El Paso)ss

John R. Copple, of lawful age, being first duly sworn, on oath says, that (s)he is the agent authorized by the bidder to submit the attached bid. Affidavit further states that the bidder has not been a party to any collusion among bidders in restraint to freedom of competition by agreement to bid at a fixed price or to refrain from bidding; or with any city official or employee as to quantity, quality, or price in the prospective contract, or any other terms of prospective contract; or in any discussion between bidders and any city official concerning exchange of money or other thing of value for special consideration in the letting of a contract; that the bidder/contractor has not paid, given or donated or agreed to pay, give or donate to any officer or employee of the City of Midwest City, Oklahoma any money or other thing of value, either directly or indirectly, in the procuring of the award of a contract pursuant to this bid.

The Sanborn Map Company, Inc.
Bidder

By: [signature]

Subscribed and sworn to before me on this 5th day of December, 20 18

[signature] Emma

My Commission Expires 30 June 2021

EMMA S NORTHUP
Notary Public
State of Colorado
Notary ID # 20094020968
My Commission Expires 06-30-2021

AFFIDAVIT OF NON-COLLUSION

City of Moore, OK

STATE OF Colorado)

COUNTY OF El Paso)ss

John R. Copple, of lawful age, being first duly sworn, on oath says, that (s)he is the agent authorized by the bidder to submit the attached bid. Affidavit further states that the bidder has not been a party to any collusion among bidders in restraint to freedom of competition by agreement to bid at a fixed price or to refrain from bidding; or with any city official or employee as to quantity, quality, or price in the prospective contract, or any other terms of prospective contract; or in any discussion between bidders and any city official concerning exchange of money or other thing of value for special consideration in the letting of a contract; that the bidder/contractor has not paid, given or donated or agreed to pay, give or donate to any officer or employee of the City of Moore, Oklahoma any money or other thing of value, either directly or indirectly, in the procuring of the award of a contract pursuant to this bid.

The Sanborn Map Company, Inc.
Bidder

By: ______________

Subscribed and sworn to before me on this 5th day of December, 2018

____

My Commission Expires 30 June 2021

EMMA S NORTHUP
Notary Public
State of Colorado
Notary ID # 20094020968
My Commission Expires 06-30-2021

AFFIDAVIT OF NON-COLLUSION

City of Norman, OK

STATE OF Colorado)

COUNTY OF El Paso)ss

John R. Copple, of lawful age, being first duly sworn, on oath says, that (s)he is the agent authorized by the bidder to submit the attached bid. Affidavit further states that the bidder has not been a party to any collusion among bidders in restraint to freedom of competition by agreement to bid at a fixed price or to refrain from bidding; or with any city official or employee as to quantity, quality, or price in the prospective contract, or any other terms of prospective contract; or in any discussion between bidders and any city official concerning exchange of money or other thing of value for special consideration in the letting of a contract; that the bidder/contractor has not paid, given or donated or agreed to pay, give or donate to any officer or employee of the City of Norman, Oklahoma any money or other thing of value, either directly or indirectly, in the procuring of the award of a contract pursuant to this bid.

The Sanborn Map Company, Inc.
Bidder

By: [signature]

Subscribed and sworn to before me on this 5th day of December, 20 18

[signature]

My Commission Expires 30 June 2021

EMMA S NORTHUP
Notary Public
State of Colorado
Notary ID # 20094020968
My Commission Expires 06-30-2021

AFFIDAVIT OF NON-COLLUSION

County of Canadian County, OK

STATE OF Colorado)

COUNTY OF El Paso)ss

John R. Copple, of lawful age, being first duly sworn, on oath says, that (s)he is the agent authorized by the bidder to submit the attached bid. Affidavit further states that the bidder has not been a party to any collusion among bidders in restraint to freedom of competition by agreement to bid at a fixed price or to refrain from bidding; or with any city official or employee as to quantity, quality, or price in the prospective contract, or any other terms of prospective contract; or in any discussion between bidders and any city official concerning exchange of money or other thing of value for special consideration in the letting of a contract; that the bidder/contractor has not paid, given or donated or agreed to pay, give or donate to any officer or employee of the County of Canadian County, Oklahoma any money or other thing of value, either directly or indirectly, in the procuring of the award of a contract pursuant to this bid.

The Sanborn Map Company, Inc.
Bidder

By: [signature]

Subscribed and sworn to before me on this 5th day of December, 2018

[signature]

My Commission Expires 30 June 2021

EMMA S NORTHUP
Notary Public
State of Colorado
Notary ID # 20094020968
My Commission Expires 06-30-2021

AFFIDAVIT OF NON-COLLUSION

Association of Central Oklahoma Governments (ACOG), OK

STATE OF Colorado)

COUNTY OF El Paso)ss

John R. Copple, of lawful age, being first duly sworn, on oath says, that (s)he is the agent authorized by the bidder to submit the attached bid. Affidavit further states that the bidder has not been a party to any collusion among bidders in restraint to freedom of competition by agreement to bid at a fixed price or to refrain from bidding; or with any city official or employee as to quantity, quality, or price in the prospective contract, or any other terms of prospective contract; or in any discussion between bidders and any city official concerning exchange of money or other thing of value for special consideration in the letting of a contract; that the bidder/contractor has not paid, given or donated or agreed to pay, give or donate to any officer or employee of the Association of Central Oklahoma Governments (ACOG), Oklahoma any money or other thing of value, either directly or indirectly, in the procuring of the award of a contract pursuant to this bid.

The Sanborn Map Company, Inc.
Bidder

By: [signature]

Subscribed and sworn to before me on this 5th day of December, 20 18

[signature] My Commission Expires 30 June 2021

EMMA S NORTHUP
Notary Public
State of Colorado
Notary ID # 20094020968
My Commission Expires 06-30-2021

Appendix

Resumes

The following are resumes of Sanborn's proposed key personnel and subcontractors.

Bridget Marcotte, PMP

Project Manager

Ms. Marcotte has more than 13 years of experience in the GIS/mapping industry, utilizing remote sensing and GIS technology to deliver innovative and quality land cover classifications and data analysis to clients. Ms. Marcotte has experience providing state-of-the-art applications of photogrammetry, remote sensing, and GIS to address real-world issues. Ms. Marcotte is currently a Project Manager. As project manager she oversees project timelines and budgets, and works directly with clients to ensure project success. She has had direct accountability for project development and execution throughout the project management lifecycle including proposal writing; project scheduling; project deliverables; production and QC; project budgeting; and controlling all aspects of projects in accordance with contract documents. Ms. Marcotte has significant experience in managing all phases of oblique and orthoimagery, LiDAR, GIS and remote sensing projects.

Education

- **Urban Forest and Wildlife Habitat Steward, TX 2015**
- **Certificate of Completion Project Management Course** – Portland State University, Portland, OR 2010
- **BA, Anthropology** – University of Texas at Arlington, Arlington, TX, 2004
- **BS, GIS/Remote Sensing** – Texas State University, San Marcos, TX, 2000

Affiliations and Certifications

- **Certified Project Management Professional (PMP) –** Project Management Institute, No. 1977614, 2019

Project Experience

- **Sacramento Color Orthophotography and Oblique Imagery Services, California, January 2018—Present.** Ms. Marcotte serves as the Project Manager. This project is a collaborative purchase of the acquisition and processing of 1,549 square miles of 3-inch orthoimagery and 990 square miles of 6-inch oblique imagery; both resolutions will have orthoimagery created from the oblique nadirs.
- **Ventura County Color Orthophotography and Oblique Imagery Services, California, October 2017—Present.** Ms. Marcotte serves as the Project Manager. This project consists of the acquisition and processing of 813 square miles of 6-inch orthoimagery and 1,084 square miles of 4-inch oblique imagery with orthoimagery created from the oblique nadirs.
- **Central Coast Color Orthophotography and Oblique Imagery Services, California, October 2017—Present.** Ms. Marcotte serves as the Project Manager. This project is a collaborative purchase of the following imagery services: 760 square miles of 12-inch orthoimagery, 478 square miles of 6-inch orthoimagery, 600 square miles of 3-inch orthoimagery, 108 square miles of 3-inch oblique imagery with orthoimagery created from the oblique nadirs and 325 square miles of 9-inch oblique imagery.
- **TX Shoreline Orthoimagery, Texas Water Development Board, Texas, June 2017—November 2017.** Ms. Marcotte served as the Project Manager. This project consisted of the acquisition of 4-band, 6-inch imagery for 62 square miles along the Texas Gulf Coast, and the production of orthoimagery.
- **Denton County, Texas, March 2017—January 2018.** Ms. Marcotte served as the Project Manager for this approximately 1,015-square-mile project. This project consists of the acquisition of Quality Level 2 LiDAR, hydro-flattened breaklines, 1-foot contours, and Raster DEM.
- **Coastal LiDAR, Texas Water Development Board, Texas, February 2017—Present.** Ms. Marcotte serves as the Project Manager for this approximately 1,130-square-mile project. This project consists of the acquisition of 4ppm and 8ppm LiDAR data, hydro-flattened breaklines, intensity images, and Raster DEM.
- **Butler County, Kansas, January 2017—October 2017.** Ms. Marcotte served as the Project Manager. This project consists of the acquisition of 4-band, 6-inch and 16-inch imagery for 1,594.5-square miles and the production of orthoimagery.
- **Santa Clara County, California, November 2016—Present**. Ms. Marcotte serves as the Project Manager for this approximately 1,682 square-mile project. This project consists of acquiring and delivering 3-inch, 6-inch

and 9-inch orthoimagery, Quality Level 2 LiDAR data, LiDAR-derived 2D and 3D building wireframes, change detection and cloud hosting services.

- **Stanislaus County, California, November 2016—January 2018.** Ms. Marcotte served as the Project Manager. This project consists of the acquisition of 4-band, 6-inch imagery for 1,533-square miles and the production of orthoimagery.
- **City of Haines and Winter Park LiDAR, South Florida Water Management (SWFWMD), Florida, November 2016—Present**. The project includes the acquisition of 8 points per meter LiDAR elevation data, calibration, processing and derivative product development, including hydro-flattening and hydro-enforcement. The project also includes semi-automated collection of project-specific impervious features (building rooftops, roads, driveways and parking lots). Ms. Marcotte serves as project manager and primary point of contact.
- **San Mateo County, California, October 2016—February 2018.** Ms. Marcotte served as the Project Manager for this approximately 547.7-square-mile project. This project consists of acquiring and delivering 6-inch orthoimagery, Quality Level 1 LiDAR data, hydro-flattened breaklines, 2-foot contours, LiDAR-derived 2D building wireframes, and vegetation footprints.
- **Aerial Imagery and Plant Community Mapping in the Floodplain of the Upper St. Johns River, Florida, February 2015—Present.** Ms. Marcotte serves as the Production Manager. This project is to monitor plant community changes in the Upper St. Johns River Basin. This project consists of the acquisition of 4-band, 1-foot imagery, change detection and mapping of plant communities.
- **City of Edmond, Oklahoma, January 2016—June 2017.** Ms. Marcotte served as the Project Manager for this approximately 127-square-mile project. The project included acquisition of 3-inch imagery and Quality Level 2 (QL2) LiDAR, and development of a hydro-flattened digital elevation model and 1-foot contours, and of 4-band 3-inch orthoimagery.
- **Farmington, New Mexico, August 2016—March 2017.** Ms. Marcotte served as the Project Manager for this approximately 1,485-square-mile project. This project consisted of the acquisition of Quality Level 2 (QL2) LiDAR, hydroflattened breaklines/DEM, and Raster DEM.
- **Yavapai County LiDAR, Arizona, January 2016—November 2016.** Ms. Marcotte served as the Project Manager for this approximately 200-square-mile project. This project consisted of the acquisition of Quality Level 2 (QL2) LiDAR, hydroflattened/hydro-enforced breaklines, Raster DEM, Raster DTM and 2-foot contours.
- **Austin Park LiDAR, Texas, February 2016—November 2016.** Ms. Marcotte served as the Project Manager. This project consisted of the acquisition of Quality Level 2 (QL2) LiDAR, breaklines, DEM and 1-foot contours.
- **Red River TX/OK LiDAR, Texas/Oklahoma, March 2016—November 2016.** Ms. Marcotte served as the Project Manager for this approximately 488-square-mile project. This project consisted of the acquisition of Quality Level 1 (QL1) LiDAR, hydroflattened breaklines/DEM, Raster DEM and 1-foot contours.
- **Defiance County Aerial Photography, Ohio, December 2015—November 2016.** Ms. Marcotte served as the Project Manager. This project consisted of the acquisition of 3-band, 6-inch imagery and the production of orthoimagery.
- **Regional Digital Orthophoto Images and Associated Data, Oklahoma, November 2015—November 2016.** Ms. Marcotte served as the Project Manager. This project consisted of the acquisition of 3-inch, 6-inch, and 12-inch imagery and LiDAR; and the development of orthoimagery, topography, planimetric (new collection and change detection), and metadata.
- **Digital Orthophotos and Geographic Information System Base Datasets, Oklahoma, November 2015—November 2016.** Ms. Marcotte served as the Project Manager. This project consisted of the acquisition of 4-band, 6-inch imagery and LiDAR; and the development of orthoimagery, topography, planimetric (new collection and change detection), and metadata.
- **MI Building Outline Updates, Michigan, September 2015—October 2016.** Ms. Marcotte served as the Project Manager. This project consisted of updating building footprints.

- **2015 Aerial Image Acquisition for Merritt, British Columbia, Canada, June 2015—August 2016.** Ms. Marcotte served as the Project Manager. This project consisted of the acquisition of 4-band, 30-cm imagery.
- **California Water Service, California, December 2014—October 2015.** Ms. Marcotte served as the Project Manager. The purpose of this project was to identify opportunities to reduce the difference between the water needed to efficiently irrigate landscape and the actual water used. This was accomplished through the use of GIS and remote sensing techniques such as impervious land cover mapping.
- **Broadband Mapping, Washington, Connecticut, and Oklahoma, March 2010—December 2014.** Ms. Marcotte was the data coordinator for Washington, Oklahoma, and Connecticut and worked with broadband providers to request data, convince providers to participate, help them in putting their data together, undertake data triage and validate data.
- **Broadband Mapping, Georgia, Match 2010—December 2012 and January 2013—April 2015.** Ms. Marcotte served as the data coordinator for the data collection and review portion of this project. The program was a national effort to map broadband in the country to identify unserved and underserved areas.
- **Oregon State Broadband Mapping Program, March 2010—June 2012.** Ms. Marcotte served as the project manager and GIS analyst for the addressing portion of this project. This program was to identify, locate, and populate address information for identified counties in Oregon.

Work History

- **Project Manager/Project Manager Associate, Sanborn, Austin, Texas, April 2013—Present.** Supports the Project Management Office and acts as lead on assigned projects. Provides status reporting in support of PMO group. Provides extensive support with project management and planning software for scheduling and Earned Value Analysis tracking. Assists in monitoring cost to budget performance.
- **Remote Sensing/GIS Analyst, Sanborn, Portland, Oregon, March 2010—April 2013.** Collected, analyzed and processed geospatial data in multiple formats using stereo compilation, GIS and/or remote sensing techniques. Provided quality review of GIS products associated with data collection, data processing and validation.
- **On-site Contract Staff, USDA/NRCS, Sanborn, Multiple Sites, 2006—2010.** This was an on-site government contract that used remote sensing to determine land use and change detection of natural resources on U.S. lands.
    - **Project Manager, Portland, Oregon, September 2008—March 2010.** Responsible for monitoring projects and contract staff in the Portland lab to ensure that goals and standards were met; responsible for running day-to-day operations. Responsible for scheduling, budget and administrative matters for contract staff.
    - **Remote Sensing Specialist, Fort Worth, Texas, August 2007—September 2008.** Responsible for providing training to staff in image-to-image registration (IIR), location certification (LC) and data collection (DC). Performed and trained photo interpretation skills to distinguish vegetation types, natural resources and land features. Contributor to the creation of Sanborn IIR and DC training modules; organized already developed NRCS training material, created training plans and schedule, helped define critical and non-critical errors in the data. Supervised and conducted quality control process and provided technical support to staff.
    - **Data Collection Team Lead, Fort Worth, Texas, December 2006—August 2007.** Supervised and provided technical support to staff performing IIR, LC and DC. Responsible for some administrative matters such as employee PTO, employee development and policy. Conducted data collection quality control, analyzed quality control results and provided feedback to staff. Contractor point of contact for data collection issues.
- **Photogrammetry Team Lead, Fugro Earthdata, Frederick, Maryland, December 2000—November 2002.** Responsible for the timely and successful completion of multiple projects. Responsible for scheduling, budget, ensuring accuracy standards, and final completion were met for aerial triangulation and stereo compilation projects.

S. Tait Fisher

Lead Pilot – Aerial Mapping Acquisition Team

Mr. Fisher has more than 35 years of experience as a pilot operating in a wide variety of aviation operations and holds an Airline Transport Pilot certificate. Prior to Mr. Fisher's career with Sanborn, he has been employed as both a UPS and USPS cargo pilot delivering freight throughout the western US region. Mr. Fisher has also gained extensive experience operating nationwide as an FAA part 135 charter and air ambulance pilot in both Learjet and King Air type aircraft. Mr. Fisher has also been employed as an airline pilot with United Express and has always maintained current certificates and ratings as a Flight Instructor with Single Engine, Multi Engine, Instrument, and Advanced Ground Instructor Ratings.

Education

- **Associate of Applied Science degree in Aviation Technology** – Aims College, Greeley, Colorado, 1989. Graduated with Honors and on the Dean's List.
- Specialized ongoing education at various colleges and aviation training facilities.

Affiliations and Certifications

- Airline Transport Pilot Certificate
- Flight Instructor: Airplane Single Engine, Multi Engine, Instrument, Advanced Ground Instructor.
- Extensive weather flying experience.
- Extensive mountain flying experience.
- Extensive single pilot IFR experience.

Project Experience

Below are examples of projects flown and completed during Mr. Fisher's employment with Sanborn:

- **New York Cyber Security and Critical Infrastructure**
- **Washington DC (DC OCTO)**
- **Maricopa County, Arizona**
- **Various Mexico projects**
- **NAIP Imagery**

Work History

- **Lead Pilot, Sanborn, Colorado Springs, Colorado, June 2016 – Present.** Oversees aircraft and flight crew movement and coordinates with the acquisition team to achieve the highest quality and most efficient collection procedures possible. Works closely with the aircraft maintenance department helping manage data tracking and record keeping for an extensive fleet of aircraft ranging from single engine Cessna's to twin turbine aircraft. Maintains a high level of pilot training and continued education programs.
- **Pilot, Sanborn, Colorado Springs, CO, 2008—June 2016.** Aircraft pilot for data and imagery collection.
- **Captain, Key Lime Air, Centennial, CO, February 2007 – October 2007.** Highly skilled single-pilot transport of UPS freight regionally utilizing PA31-350 aircraft in a wide variety of weather conditions and airport operations.
- **First Officer, International Jet Aviation Services, Centennial, CO, October 2000 – March 2001.** Nationwide Part 135 on demand charter, freight, and air ambulance operations.
- **Captain, Alpine Air, Billings, MT, April 1998 – January 1999.** Both multi crew and single-pilot IFR transport of USPS freight regionally in turbine BE-99 aircraft.
- **First Officer, Mesa Airlines, Farmington, NM, July 1992 – October 1995.** (United Express) passenger carrying airline operations in BE-1900 aircraft.

Yvonne Harding, GISP, SC GIS Surveyor

Manager of Operations/GIS Manager

Ms. Harding has over 17 years of experience in many phases of digital mapping and orthophotography production, and is currently the GIS Team Manager for the entire organization as well as the Operations Manager for Sanborn's Charlotte, North Carolina, location. Ms. Harding's responsibility is to supervise, facilitate, and ensure quality standards are met for each mapping project. Ms. Harding utilizes multiple GIS software, such as ArcGIS, MicroStation, and AutoCAD, for quality control verification.

Education

- **BS, Earth Sciences**—University of North Carolina at Charlotte, Charlotte, NC, 1998

Affiliations and Certifications

- **Geographic Information Systems Professional (GISP)**—GIS Certification Institute, No. 60209, 2008
- **Professional GIS Surveyor**—South Carolina, No. 24118, 2004
- **Integrated Distance Learning Environment (FAA IDLE)**—Level 3 Training for FAA Advisory Circulars AC 150/5300-16A – AC 150/5300-17B – AC 150/5300-18B, No. FAAIDLE20121130-256, 2012
- **American Society for Photogrammetry and Remote Sensing (ASPRS)**—Member, 2011
- **Geospatial Information & Technology Association (GITA)**—Member, 2011
- **Urban and Regional Information Systems Association (URISA)**—Member, 2009

Professional Education/Seminars

- **Airports GIS Workshop,** 2012
- **FAA IDLE Training,** AC 150 5300-18 Survey Data and GIS Standards, 2012
- **Advanced Analysis with ArcGIS,** 2006
- **Building Geodatabases II,** 2004
- **Creating and Managing Geodatabases,** 2001

Project Experience

- **Connecticut Statewide, Capital Region Council of Governments (CRCOG), CT, April 2016—December 2016.** Ms. Harding was the GIS supervisor for this project; verifying the final QC and topology check this project and all additional City buy-ups as listed below. For this project, Sanborn was contracted by the State of Connecticut to provide statewide coverage (approximately 5,100 square miles) of 3-inch orthoimagery, QL2 LiDAR, and 1-foot and 5-foot contours. The aerial imagery was collected in the spring of 2016. Additional services included: ground control surveys to support the project, aerial triangulation to tie the new aerial photography and verify the ground control, new 3-inch, 4-band, 8-bit, RGB/NIR digital orthophotography tiles in GeoTIFF and MrSID formats, new QL2 USGS-compliant LiDAR for the entire state, a new bare-earth, hydro-flattened DEM to support orthorectification and contour production, a new 1-foot and 5-foot contour data set and MrSID orthomosaics for each town. Listed below are several municipalities, organizations and companies that procured database development through this CRCOG Spring 2016 Statewide GIS Acquisition and Services buy-up program:
  - Connecticut Water Company
  - Town of Enfield
  - The Mohegan Tribe of Connecticut
  - Town of Cromwell
  - Town of Ellington
  - Town of Haddam
  - Town of Ledyard
  - Town of East Haddam
- **Southern Connecticut Gas Company (SGC), CT, December 2016—December 2017.** SGC was in the process of implementing an Esri ArcGIS-based Geographic Information System (GIS); this system used the digital orthophotography and data sets created by Sanborn through the Capital Region Council of Governments (CRCOG) spring 2016 Statewide GIS Acquisition and Services buy-up program (as listed above). SGC contracted Sanborn to provide a geodatabase design, perform prototyping, a pilot project and planimetric

data extraction to develop an Esri ArcGIS planimetric database and MicroStation .DGN CAD file set for features in a 594.4 square mile project area. Ms. Harding was the GIS supervisor this project; verifying the final quality assurance and control and the generation of the metadata for this project.

- **Loudoun County, Virginia, July 2014—Present.** Responsible for GIS QC and delivery of updated 1:2400 scale, 4-foot contour interval planimetric and topographic mapping.
- **March Air Reserve Base (ARB), Riverside, CA, October 2016—May 2017.** Sanborn collected Obstacle/Obstruction data for all ground and elevated features that penetrate the Airspace surfaces and clearance for March ARB. Sanborn acquired this data by using aerial photography and aerial LiDAR data to produce an Airfield Obstruction Survey for the airfield and surrounding area, with mapping products, including ground elevation contours, tree canopy points and GIS products with orthorectified aerial photography, 3D buildings, and prints. Oblique imagery was also collected for this project with 2.5-inch resolution. Oblique images were delivered together with the Sanborn Oblique Analyst® viewer software. A terrestrial scan of 5 hangars was also performed and 3D LAS files produced. Ms. Harding was the GIS supervisor for this project; verifying the final QC and topology check for project.
- **Grissom Air Reserve Base (ARB), 12 Miles North of Kokomo, IN, October 2016—May 2017.** Sanborn collected Obstacle/Obstruction data for all ground and elevated features that penetrate the airspace surfaces and clearance for Grissom ARB. Sanborn acquired this data by using aerial photography and aerial LiDAR data to produce an Airfield Obstruction Survey for the airfield and surrounding area, with mapping products, including ground elevation contours, tree canopy points and GIS products with orthorectified aerial photography, 3D buildings, prints, oblique imagery and the Sanborn Oblique Analyst®; and a terrestrial scan of 6 hangars. Ms. Harding was the GIS supervisor for this project; verifying the final QC and topology check for project.
- **Nantucket, Massachusetts, June 2014—November 2014.** Responsible for GIS QC and delivery of 1"=40' scale, 2-foot contour interval planimetric, topographic and orthophoto mapping.
- **Gwinnett County, Georgia, November 2013—Present.** Responsible for GIS QC and delivery of updated planimetric and topographic data for 1" = 100' scale mapping for Gwinnett County. Our performance has led to award of additional years of updating projects.
- **Greater Bridgeport Regional Council, Bridgeport, Connecticut, November 2013—June 2014.** Responsible for GIS QC and delivery of planimetric data for 1"=50' scale mapping, including annotation contours. Also responsible for creating, editing and QC'ing topographic data.
- **North Carolina Department of Transportation, North Carolina, September 2000—Present.** Under an open-ended contract to perform mapping services for various roadway projects throughout the state, Ms. Harding performs quality control of MicroStation design file format topographic mapping and Geopak DTM data to ensure conformity to NCDOT's Mapping Standards.
- **City of Baltimore, Maryland, May 2008—August 2009.** Ms. Harding oversaw the production of planimetric and 1-foot/2-foot contour update mapping and performed quality control verification using the ArcGIS PLTS extension.
- **Oconee Nuclear Station, South Carolina, March 2010—June 2010.** Ms. Harding oversaw the production and QA/QC of planimetric and DTM stereo-collection to support 1"=50' scale, one-foot contour interval topographic mapping, and 0.25-foot pixel resolution orthophotography of approximately 2,000 acres.
- **Beverly Municipal Airport, Massachusetts, June 2012—October 2012.** Ms. Harding supervised the collection of 1"=200' scale planimetric mapping and obstructions via stereo-collection to conform to FAA AC 150 5300-18B Survey Data and GIS Standards, and development of DEM collection to support orthophotography to conform to FAA AC 150 5300-17 Imagery Standards.
- **Hartness State Airport (KVSF) Springfield, Vermont, September 2012—November 2012.** Ms. Harding supervised the collection of 1"=50' scale one-foot contour interval topographic mapping of the 238 acre ALP area. The planimetric features included 3D buildings, runways, taxiways, airport parking outlines, runway and taxiway pavement markings, paved/unpaved roadways and parking areas, utility poles, vegetation and hydrology. In addition, obstruction mapping of the 14,310 acre area was performed to conform, to Part 77 specifications.

- **Charleston Air Force Base, South Carolina, May 2011—November 2011.** Ms. Harding supervised the production of obstruction mapping for Runways 15/33, 3/21 and 6/24 based on approach surfaces defined in UFC 3-260-01 for Class B.
- **Charlotte Douglas International Airport, North Carolina, March 2010—October 2010.** Ms. Harding supervised the production of 1"=50' scale planimetric and DTM mapping to support 1-foot contours for As-built Survey of Runways 36L/18R and 18C/36C to conform to NSSDA-FGDC standards.
- **Greenville Spartanburg Airport, South Carolina, March 2011—December 2011.** Ms. Harding supervised the production of 1"=100' planimetric and DTM mapping to support 5-foot contours for a 3,766-acre land use study area.
- **Blacksburg Quarry, Cherokee County, South Carolina, December 2012—January 2013.** Ms. Harding supervised the production of 1"=100' scale two-foot interval contour mapping in AutoCAD format. In addition, she performed the volumetric calculations for the quarry's inventory purposes.
- **Cape Girardeau Quarry, Missouri, December 2012—January 2013.** Ms. Harding supervised the production of 1"=100' scale, two-foot contour interval planimetric, DTM and topographic mapping in AutoCAD format. In addition, she performed the volumetric calculations for the quarry's inventory purposes. This project is usually updated annually for client.

Work History

- **GIS Team Manager/Manager of Operations, Sanborn, Charlotte, North Carolina, May 2010—Present.** Ms. Harding is currently responsible for management of GIS mapping production for Sanborn, and for management of mapping production in all phases for the Charlotte location.
- **GIS Analyst, Sanborn, Charlotte, North Carolina, July 1999—May 2010.** Ms. Harding has held multiple production roles including cartographic edit, orthophotography and GIS production. During this time she was responsible for quality control of cartographic edit and GIS products as well as training for production staff.

Craig Laben

Geospatial Data Manager

Mr. Laben has over 20 years of experience in remote sensing, GIS, image processing, geospatial analysis and geospatial product quality assurance. He has extensive knowledge of commercial and government satellite and aerial EO, MS, IR and radar imaging systems data and their applications. Mr. Laben has developed algorithms, techniques, processes and metrics to improve the image quality, accuracy and intelligence value of geospatial products. He also has experience in the processing and analysis of geospatial and natural hazards data for damage assessments, risk and vulnerability assessments and mitigation strategies. Mr. Laben has strong department management, project management and technical leadership experience, and has excellent analytical and problem solving skills.

Education

- **MS, Imaging Science –** Rochester Institute of Technology, Rochester, NY, 1993
- **BS, Computer Science** – Rochester Institute of Technology, Rochester, NY, 1986
- **AAS, Computer Science** – Rochester Institute of Technology, Rochester, NY, 1986

Computer Skills

- **Programming** — MATLAB, Python scripting
- **Remote Sensing and GIS Tools** — ESRI ArcGIS, ERDAS Imagine, ENVI, SocetGXP, Socet Set, RemoteView, QTModeler, ERMapper, Photoshop, LightRoom, OrthoVista, UltraMap, Global Mapper

Publications

- C. Chiesa, P. Cower, C. Laben (2004, Jul). ***"Mapping Flood Risk and Vulnerability in the Lower Mekong Delta,"*** ESRI Map Book Gallery Vol. 20
- C. Laben, (2004, Mar). ***"An Asia Pacific Natural Hazards and Vulnerabilities Atlas Supporting Disaster Management Applications."*** Pacific Disaster Center White Paper
- C. Chiesa, C. Laben, R. Cicone (2003, Nov). ***"An Asia Pacific Natural Hazards and Vulnerabilities Atlas."*** Proceedings, International Symposium for Remote Sensing of the Environment (ISRSE), Honolulu
- C. Laben (2002, Sept) ***"Integration of Remote Sensing Data and Geographic Information System Technology for Emergency Managers and their Applications."*** Optical Engineering, Journal for the International Society for Optical Engineering, Vol. 41, No. 9

Patents

- C. Laben, B.Brower (2000, Jan). ***"A Process for Enhancing the Spatial Resolution of Multispectral Imagery using Pan-Sharpening."*** US Patent #6,011,875
- R. Fiete, C. Laben (1999, Mar). ***"An Adaptive Process for Removing Streaks in Digital Images."*** US Patent #5,881,182

Project Experience

- **Oblique Imagery Program, Customer Confidential, Multiple Cities Across the USA, November 2013 – Present.** Mr. Laben currently manages the QC, image processing and color balancing of all acquired oblique aerial imagery data for the large oblique imagery program. In 2015 alone, over 3,000,000 images, encompassing over 8,300 square miles, were processed, reviewed, color balanced and successfully delivered to the customer.
- **Washington DC OCTO Program, Washington DC, February 2015 – February 2016.** Mr. Laben was responsible for the QC, color balancing and enhancement of all orthophotography and oblique imagery collected for the Washington DC OCTO program. For this program, Sanborn flew LiDAR, orthophotography and oblique imagery simultaneously using three different sensors. This data was processed and combined to produce photogrammetric, GIS and imagery products. The oblique imagery was also delivered to the customer in Sanborn's Oblique Analyst (SOA) viewing application.
- **US Cities Oblique Program, Multiple Cities across the USA, October 2013 – Present.** Mr. Laben currently manages the Quality Control and delivery of all acquired aerial imagery data for Sanborn's US Cities Oblique Program. He is responsible for ensuring that staffing requirements are maintained and that all project deliveries are made on-time and within budget, while making sure that all customer quality standards are being met. He is also responsible for identifying areas in the Image Quality processing work flows for improvement and making sure that process enhancements are developed, implemented and documented.
- **Maricopa County Orthoimagery Program, Maricopa County, Arizona, October 2013 – Present.** Mr. Laben is currently responsible for the QC, color balancing and enhancement of all color and NIR digital imagery collected at 3-inch, 6-inch and 1-foot resolutions for the County of Maricopa Program.
- **McLean County Regional GIS Consortium, Illinois, February 2014 – October 2014.** Mr. Laben was responsible for the QC, color balancing and enhancement of all oblique imagery collected for the McLean

County Program. He was also responsible for staging the data for implementation into the Sanborn Oblique Analyst viewing application and testing the application for completeness and accuracy.

- **Lockheed Martin Corp., Goodyear, Arizona, June 2010 – August 2011.** Mr. Laben was the technical lead on a government contract and was responsible for developing image quality metrics that are currently being used to assess the quality and accuracy of national geospatial products. These image quality metrics include: visual ratings, local and global statistical analysis, geo-location and mensuration analysis, histogram analysis and metadata verification techniques.
- **Pacific Disaster Center, Maui, Hawaii, October 2002 – October 2004.** Mr. Laben was the project lead for the design, implementation and deployment of the Pacific Disaster Center's Global Hazards Atlas. The Global Hazards Atlas is an internet mapping application which can be used to display near real-time and historical natural hazards data around the globe. The Global Hazards Atlas may be accessed at: www.pdc.org/atlas.
- **Eastman Kodak Company, Rochester, New York, May 1998 – January 2000.** Under a government contract, Mr. Laben developed a Gram-Schmidt transform pan-sharpening technique that improved the spatial resolution of multispectral (MS) imagery using a higher resolution panchromatic image, but maintained the spectral characteristics of the MS imagery. Mr. Laben documented, submitted for, and received a patent for this Gram-Schmidt pan-sharpening technique. This algorithm is currently offered in both ESRI's ArcGIS and EXELIS' ENVI remote sensing software packages.

Work History

- **Geospatial Data Manager, Sanborn, Colorado Springs, Colorado, October 2013 – Present.** Mr. Laben is currently the Image Processing Department Manager and oversees the day-to-day activities which include data ingestion, processing, color balancing and imagery QC for all aerial projects within Sanborn's mapping operations. Mr. Laben is responsible for coordinating activities between the flight acquisition team and the production team and ensuring that image quality and accuracy standards are being met. Mr. Laben works with the GPS-IMU and Imagery QC teams to optimize workflows and to develop more efficient processes to improve data ingest and QC turn-around times and lower associated costs.
- **Signal/Image Processing Engineer, Sr. Staff., Lockheed Martin Corp., Goodyear, Arizona, February 2005 – August 2012.** Mr. Laben was a member of the Geospatial Product Quality (PQ) group which performed geospatial product quality assurance and accuracy assessments on national remote sensing products/tools for various government and defense agencies. Mr. Laben was technical lead on multiple programs and was responsible for all PQ activities related to these programs to include: developing detailed test plans, assigning tasks, performing manual and automated regression testing, performing geo-location and mensuration accuracy assessments, identifying/logging/tracking issues, performing issue resolution and verification, and performing requirement verification. As a technical lead, Mr. Laben was responsible for ensuring that all projects were staffed appropriately and were completed on time and within budget. In addition, Mr. Laben developed Standard Operating Procedures (SOPs), regression testing checklists and image quality metrics for the testing of baseline and Advanced Geospatial Intelligence (AGI) products.
- **Sr. Imagery Analyst, Lockheed Martin Corp, Kihei, Maui, Hawaii, January 2001 – February 2005.** As a subcontractor, Mr. Laben was a member of the Data and Information Resources Division at the Pacific Disaster Center located in Maui, Hawaii. The PDC utilizes remote sensing and GIS data, impact modeling, risk assessment tools, and visualizations to provide emergency managers, decision makers and disaster management professionals with historical and real-time hazards information products. Mr. Laben coordinated with and conducted various remote sensing and GIS projects for local, state and federal emergency response agencies. Mr. Laben processed and analyzed natural hazards and geospatial data for risk and vulnerability assessments and mitigation strategies. He also was responsible for integrating real-time hazards data into PDC geospatial applications. Additionally, Mr. Laben tasked and trained PDC Imagery Analysts and GIS interns.
- **Imagery Analyst, Eastman Kodak Co., Kihei, Maui, Hawaii, February 1999 – January 2001.** Mr. Laben joined the PDC in its early years as an Imagery Analyst, where he produced geospatial products for the disaster management community. As an Imagery Analyst, his duties included: base map imagery and GIS data collection, data processing and mosaic generation, metadata documentation and verification, database population, development of change detection techniques and products, damage assessments during and after a hazard/disaster event, geospatial product development, and post-event product generation.

Jared Martin, CP, CMS, CST

LiDAR Manager

Mr. Jared Martin has more than 7 years of experience in the remote sensing profession. He has supervised and worked on programs ranging from multi-year large area projects to small area, high accuracy, quick-turn emergency response projects. During his career he has refined his technical and managerial expertise by accumulating working knowledge in both small and large business environments. Mr. Martin has demonstrated his subject matter expertise in utilizing LiDAR data and technology from multiple platforms by developing and improving existing business processes resulting in better geospatial decision making.

Education

- **B.S. Geography** – Kansas State University, Manhattan, KS, 2010

Affiliations and Certifications

- **Certified Survey Technician (CST)**—NSPS, No. 1012-4545, 2012
- **Certified Photogrammetrist (CP)**—ASPRS, No. 1626, 2017
- **Certified Mapping Scientist (CMS) LiDAR**—ASPRS, No. L018, 2017

Project Experience

- **State of Michigan, MiSAIL LiDAR project, Michigan, September 2017—Present.** Responsible for performing LiDAR calibration and overseeing the LiDAR production of both QL1 and QL2 data for this 13,000 square mile, multi-year program.
- **USDA Forest Service, Region 6, Multiple Projects, 2015—2017.** Mr. Martin oversaw the production and successful delivery of multiple projects consisting of state and national parks in and around Idaho, Oregon, and Washington. He led the processing effort of more than 7,000 square miles leaf-on collected USGS QL1 LiDAR and managed the editing of both internal and subcontracted deliverables. The delivered products met or exceeded client expectations in regards to early delivery and high quality.
- **United States Army Corp of Engineers, Missouri, December 2015—November 2016.** Mr. Martin served as the production manager and lead for more than 12,000 square miles of QL2 and QL3 LiDAR in the state of Missouri. Overseeing the processing and delivery of data from multiple subcontractors, he led the production effort for both internal and external technicians and analysts. This project has been successfully delivered, meeting or exceeding the client's expectations.
- **Kansas Department of Agriculture, Multiple Projects, Kansas, 2014—2017.** Mr. Martin served as the processing lead on three projects for the state of Kansas over a 3 year span. Each project consisted of USGS QL2 LiDAR and derivatives exceeding 30,000 square miles across the state. The final products delivered exceeded the client's expectations in both quality and time.
- **United States Geological Survey, Multiple Projects, Alabama, November 2016—September 2017.** Mr. Martin managed the production of two parallel USGS BAA LiDAR projects in the state of Alabama that spanned 37 counties in total. In coordination with multiple subcontractors he was responsible for the processing and delivery of QL2 LiDAR.
- **Entergy, Multi-State Corridor, May 2012—October 2013.** Mr. Martin served as the project lead for the LiDAR portion of the Entergy transmission line project. The project consisted of more than 5,000 linear right-of-way corridors throughout Arkansas, Louisiana, Mississippi, and Texas. He was responsible for the processing, QA/QC, and reporting of all LiDAR and derivatives as well as overseeing the production of project partners and subcontractors.

Work History

- **LiDAR Manager, Sanborn, Colorado Springs, CO, September 2017—Present.** As the LiDAR Manager at Sanborn, Mr. Martin Supervises and coordinates the activities and personnel of the LiDAR department, ensuring production and quality standards are met by performing the following duties personally or through subordinate personnel. He is responsible for the logistics, prioritization, development, coordination, and management of the LiDAR department in the areas of software, staffing, training, development, inventory, operation, systems analysis, and he coordinates with and supports other production staff. Mr. Martin manages workflow needs and develops and maintains department schedules to meet required service levels and to meet all project schedule requirements. He ensures proper resource allocation and oversees the overall administration of LiDAR production systems, software systems, and equipment, and identifies enhancement opportunities.

- **LiDAR Services Manager, Atlantic, Huntsville, AL, January 2014—September 2017.** As the LiDAR Services Manager at Atlantic, Mr. Martin provided functional area subject matter expertise and guidance for Atlantic's LiDAR Team. He provided subject matter oversight on all LiDAR processes and LiDAR derivative products produced by Atlantic. Mr. Martin assisted in developing and maintaining functional area workflow procedures and best practices. He conducted research and development of LiDAR products and processes to improve methods, effort, and quality.
- **LiDAR Technician II, McKim & Creed, Raleigh, NC, February 2012—December 2013.** As a LiDAR Technician II at McKim & Creed, Mr. Martin supported the internal coordination and technical aspects of LiDAR projects, including compliance with quality/specifications. He completed data processing and translations, performing the final review of LiDAR files as needed. Mr. Martin would troubleshoot and solve complex LiDAR data processing issues, and conduct and document procedure reviews of software updates and upgrades as well as implementing and tracking new tools or processes, providing feedback to the executive team. He performed technical troubleshooting and analysis for team members, extracted 2D and 3D information from the data and generated CAD mapping for delivery, and developed and led the creation of more efficient methods of classification, extraction and data quality control.
- **LiDAR and GeoCoding Team Lead, Chesapeake Bay Helicopters, Chesapeake, VA, October 2010—February 2012.** As a LiDAR and GeoCoding Team Lead at Chesapeake Bay Helicopters, Mr. Martin processed LiDAR, High Resolution Ortho Mosaics Imagery, and Geo-Located Oblique Imagery. He checked the quality of all Ortho Mosaic Imagery for in-house and out of house products as well as communicated with clients regarding project timelines and specifications. Mr. Martin was responsible for the geocoding of Oblique Imagery, Ortho Imagery, and LiDAR Datasets and would produce the metadata for those final products.

Doug Zehr, CP, SP

Chief Photogrammetrist

Mr. Zehr has 27 years of industry experience and is a member of Sanborn's photogrammetric management team. His responsibilities include project planning and design, overseeing aerial triangulation, and the support of photogrammetric and LiDAR production processes. He also works with Sanborn's business development group designing production processes.

Education

- **Graduate Studies, Geography, Physical Geography/Cartography** – Ball State University, Muncie, IN, 1986
- **BS, Earth-Space Sciences/Math** – University of Indianapolis, Indianapolis, IN, 1984

Affiliations and Certifications

- **Certified Photogrammetrist (CP)** – American Society for Photogrammetry and Remote Sensing (ASPRS), No. R1021, 1997
- **Surveyor Photogrammetrist (SP)** – Virginia, No. 0408000061, 2009
- **ASPRS –** Member, 1987
- **North Carolina Local Users Group (NCLUG) –** Member, 2013

Continuing Education and Seminars

- Photogrammetric Processing Workshop, ASPRS Webinar, 2013
- Assessing Accuracy of GID Workshop, ASPRS Conference, San Antonio, TX, 2009
- Intro to Open Source Workshop, ASPRS Conference, San Antonio, TX, 2009
- Automated Linear Feature Extraction Workshop, ASPRS Conference, Portland, OR, 2008
- Image Enhancement Workshop, ASPRS Conference, Portland, OR, 2008
- Professional Airborne Digital Mapping System Workshop, ASPRS Conference, San Antonio, TX, 2006
- LiDAR Workshop, ASPRS Conference, Charleston, SC, 2004
- IMU Workshop, ASPRS Conference, Washington, DC, 2002
- Windows 2000 Server Training Course, Washington, DC, 2002
- LiDAR Workshop, ASPRS Conference, Washington, DC, 2000
- LiDAR Realm Training, Optech, Toronto, Canada, 1999
- Orthophoto Training, Intergraph, Madison, AL, 1992

Project Experience

- **Virginia Base Mapping Program (VBMP), VA, April 2007 – February 2008; April 2009 – August 2012; March 2014 – December 2016.** Statewide orthophoto and DTM mapping program involving aerial photography collection, GPS surveys, AT, compilation, and orthophoto generation. Managed the Aerial Triangulation process for the program, beginning with statewide survey design and film based cameras in 2007, to state of the art sensors and program design in 2016. Oversaw accuracy assessment of products as ASPRS CP and Virginia Surveyor Photogrammetrist.
- **Oblique Imagery Program, Customer Confidential, Multiple Cities, March 2014 – Present.** Manages the Aerial Triangulation process for the program; overseeing sensor calibration procedures, software implementation, program design including participation in flight planning, survey planning and quality control. Works closely with the acquisition and production teams to resolve operational issues and improve efficiency.
- **State of Michigan Department of Technology Management and Budget, March 2014 – Present.** Managed the Aerial Triangulation and DEM development processes for the orthoimagery program. Worked with the data acquisition and survey teams to ensure deliverables met desired accuracy and the required projection.
- **Washington DC OCTO Program, Washington DC, February 2015 – February 2016.** Managed the Aerial Triangulation processes for both Oblique imagery collected with the MiDAS camera system and Nadir imagery with the Leica RCD30 sensor. Worked closely with hardware/software vendors and the production team on developing a true ortho workflow for the orthoimagery base map.
- **Maricopa County Orthophotos, Maricopa County, AZ, November 2007 – August 2012; March 2014 – September 2015.** Color and NIR digital imagery collected at 3-inch, 4-inch, 6-inch and 9-inch resolutions. Performed AT, DTM update, and orthophotography.
- **Florida Power & Light, Utility Mapping, FL, March 2013 – October 2013.** Color ortho and oblique imagery to support mapping of 1,600 miles of transmission lines. Performed image QC, ortho and oblique production for PLSCADD model delivery.

- **Pikes Peak Area Orthophotos, Colorado Springs Utilities, Colorado Springs, CO, March 2007 – December 2007, April 2009 – December 2009, March 2011 – December 2011, June 2014 – January 2018.** Color and NIR digital imagery collected at 0.5-foot and 1-foot resolutions for 3,000 square miles. Performed image acquisition, GPS surveys, AT, DTM update, and orthophotography.

Work History

- **Chief Photogrammetrist/AT Manager, Sanborn, Colorado Springs, CO, 2014 – Present.** Mr. Zehr manages aerial triangulation operations, and works with a team to support workflow for Sanborn's large-format digital cameras and medium-format oblique sensors. As project designer, he works closely with the business development team and estimator to ensure technical questions, concerns, and strategies are disclosed and discussed. Mr. Zehr performs evaluation of software for production and works with development teams on strategies for process improvement.
- **Production Manager, McKim & Creed, Raleigh, NC, 2012 – 2014.** As production manager, Mr. Zehr established workflows and managed photogrammetric production for utility mapping programs. He worked closely with the regional manager on estimating, budget management, and scheduling, and provided customers with innovative technical solutions to satisfy needs utilizing existing datasets. Mr. Zehr was responsible for developing production workflows utilizing MIDAS RGB/IR sensors, Harrier 68i RGB sensors and VI Nadir RGB/IR and oblique sensors. This included field and office image processing, QC procedures, AGPS/IMU processing, orthophoto production, and delivery of nadir and oblique imagery in specific projections and formats. He resolved MIDAS sensor orientation issues allowing multiple offices (multiple software packages) to join production efforts.

Publications/Presentations

- Zehr, Doug. (2004, Aug). ***"Softcopy AT,"*** Geospatial Symposium, San Antonio, TX
- Zehr, Doug. (2002, May). ***"Ortho Production Techniques,"*** Alabama Association of Assessing Officials (AAAO), Muscle Shoals, AL

- **Aerial Triangulation Manager, Sanborn, Colorado Springs, CO, 2010 – 2012.** Mr. Zehr managed aerial triangulation operations, and worked with a team to support workflow for Sanborn's nine large-format digital cameras and facilitate data integration with LiDAR and photogrammetric sensors. As project designer/estimator, he worked closely with the business development team and project managers to ensure technical questions, concerns, and strategies were disclosed and discussed. Mr. Zehr consulted with project managers to ensure all projects' technical specifications were correct and complete. He also participated in proposal meetings to discuss project specifications and to present alternate strategies when appropriate.
- **Photogrammetric Department Manager and Photogrammetric Engineer, Sanborn, Colorado Springs, CO, 2006 – 2010.** Mr. Zehr led aerial triangulation and compilation operations. In addition, he worked with a team to support workflow for Sanborn's six large-format digital cameras and facilitate data integration with LiDAR and photogrammetric sensors. As project designer/estimator, he worked closely with the business development team and project managers to ensure technical questions, concerns, and strategies were disclosed and discussed. Mr. Zehr worked on the design of specifications for the standardization of select products, and consulted with project managers to ensure all projects' technical specifications were correct and complete. He participated in proposal meetings to discuss project specifications and to present alternate strategies when appropriate.
- **Chief Photogrammetrist/Photogrammetry Department Manager, Atlantic Technologies, Huntsville, AL, 1999 – 2006.** Mr. Zehr incorporated IMU technology with film cameras. He served as project manager of IMU bore sight. Tasks included project design and specifications, AT measurement and adjustment, and evaluation and analysis of resulting data. Responsible for establishing and supporting LiDAR integration within the photogrammetric workflow with input on accuracy standards, data collection routines, and automation. Assisted in establishing production procedures, quality assurance steps, and accuracy standards. Trained and supervised technicians. Provided AT adjustments of projects ranging from 5–3,000 images using Z/I and BINGO software.

Steven A. Wood, LS, CP

Registered Land Surveyor

Mr. Wood combines an extensive land surveying and civil engineering background with more than 42 years of project management experience in engineering, land development, surveying and photogrammetry. He has developed several customized solutions for industry-leading photogrammetric projects. His surveying experience is comprehensive and includes many years of practical field assignments and office management of more than a dozen survey field crews. Projects include almost every type of surveying, including land boundary, construction staking, flood insurance cross section surveys, ALTA minimum standard surveys, power plant layout, right of way takings, GPS control surveys for control densification and photo control projects, precise second order control surveys, differential and on the fly GPS field inventory of utilities, and Department of Defense GIS mapping and field inventory. Mr. Wood has also served as the Surveyor in Responsible Charge overseeing multi-participant municipal mapping and surveying projects for many countywide landbase mapping projects throughout the US and overseas. Mr. Wood has helped implement innovative surveying uses of current technology to accomplish timely and economical survey solutions throughout his career.

Education

- **BS, Land Surveying**—Purdue University, West Lafayette, IN, 1974
- **AAS, Civil Engineering Technology—** Purdue University, West Lafayette, IN, 1972

Affiliations and Certifications

- **Certified Photogrammetrist (CP)**—ASPRS, No. R899, 1993
- **Registered Land Surveyor—**Licensed in the following 17 states: Arkansas, California, Colorado, Florida, Illinois, Indiana, Kansas, Louisiana, Maryland, Montana, New Mexico, North Carolina, Ohio, Oklahoma, Wyoming, North Dakota, South Dakota

Project Experience and Work History

- **Land Surveyor, Sanborn, Colorado Springs, CO, 2005 – Present.** Mr. Wood has performed land survey services for Sanborn for many projects, including Manistee County, Michigan: Lewis and Clark County, Montana; Ellsworth AFB, South Dakota; Clay County, Kansas; and Haskell County, Kansas.
- **Principal in Responsible Charge, privately operated small business, March 2000 – Present.** Mr. Wood is responsible for all aspects of geodetic survey control for photogrammetric mapping control of several large projects and county-wide mapping programs, including several public agencies.
  - Several surveying and mapping control projects throughout Oklahoma including work on Oklahoma City and surrounding area mapping control, several lakes throughout Oklahoma for the Corps of Engineers (COE), Fort Sill, McAlester, and various Air Force bases.
  - Several control projects in Kansas including work in Hays County, Ellis County, Anderson County, Haskel County, Garden City, Finney County, and Fort Riley. Mr. Wood also ran several COE lake mapping projects throughout Kansas.
  - Perform surveying and GIS consulting reviews of project deliverables, including the final aerotriagulation solution for DeKalb County, Indiana work performed by a large mapping industry firm.
  - GPS photo control projects for following counties/projects including Wayne County, Indiana; Brown County, Indiana; Brazil, Indiana; Bradford Woods, Indiana; Champaign County, Illinois; Lee County, Illinois; Whiteside County, Illinois; Branson, Missouri; Nauvoo, Illinois; South Lyon, Michigan; Eastern Illinois University, Illinois; Greencastle, Indiana; Alcoa Lafayette, Indiana; Peoria County, Illinois and numerous smaller local sites. Scope includes contracting NGS control recovery and densification and producing field work and office reports.
  - GPS geodetic survey photo control for DOD Air Force military installations in Kansas, Texas, Tennessee, Mississippi, Alabama, Florida, Oklahoma, Ohio, Arkansas, California, Maryland, New York, Pennsylvania, New Hampshire, and Colorado.
  - GPS photo control projects in Kansas, Illinois, Maryland, New Jersey, Kentucky, Iowa, California, and Missouri.

- GPS route survey control for MODOT highway project in Missouri.
- McAlester Army Depot, Oklahoma GPS surveys.
- Dam reclamation rehabilitation surveys in Oklahoma for USDA.
- GPS surveys in Maryland; New Jersey; Missouri; Naperville, Illinois; Canton, Illinois; Butler County, Ohio; and Lucas County, Ohio.
- GPS photo control surveys for Lamar County, Mississippi; Pike County, Mississippi; Jackson Energy, Jackson, Tennessee; City of Cleburne, Texas; Euless, Texas; Norman, Oklahoma; Lubbock, Texas; COE surveys in Bowie County, Texas and Fort Sill, Oklahoma; GPS surveys for Stark County, Illinois; McHenry County, Illinois; Jasper County, Indiana; Wayne County, Indiana; DeKalb County, Indiana; and Mesa County, Colorado.
- Extensive LIDAR quality control field checking for imagery along Mississippi River from Cairo to Minneapolis, also along the Illinois River from St. Louis to DeKalb.
- GPS control for high speed rail route from St. Louis to Chicago.
- GPS control for MD DOT mass transit lines.
- GPS control for a 13-county multi-participant mapping project around Houston.
- GPS control for a 4-county multi-participant mapping project east of Dallas.
- GPS control for a 2-county mapping project in southwest Kansas.
- GPS control for mapping projects for dozens of military sites across the US.
- Extensive LIDAR ground truthing QC surveys in Illinois, Arkansas, California, and Missouri.
- USDA NRCS WRP easement surveys in Indiana, Ohio, and Pennsylvania.

- **Vice President Photogrammetry, MSE Corporation/ASI, Indianapolis, IN, February 1993 – March 2000.** Managed production operations of state of the art photogrammetry mapping division, includes survey ground control, ABGPS, aerotriangulation, mapping, softcopy and digital orthophoto production operations. MSE was acquired by ASI in July 1997. Role expanded in 1998 to include management of corporate mapping subcontractors, coordinating work across all ASI mapping locations and reviewing and facilitating implementation of new mapping technology. Travel to New Zealand and Portugal to review mapping vendor capabilities and assist in sales efforts.
- **Vice President Operations, MSE Corporation, Indianapolis, IN, May 1983 – February 1993.** Supervised, managed, and administered production operations of over 150 employees involved in civil engineering, transportation, aviation, surveying, photogrammetry and digital computer graphics branches of company.
- **Director, Surveying and Mapping Operations, MSE Corporation, Indianapolis, IN, May 1981 – May 1983.** Combined management responsibility for all surveying and photogrammetric mapping performed by the company.
- **Director, Survey Operations, MSE Corporation, Indianapolis, IN, May 1979 – May 1981**. Directly responsible and in charge all survey operations for 12 crews for all types of surveying and civil engineering projects.
- **Survey Project Manager, MSE Corporation, Indianapolis, IN, March 1975 – May 1979**. Supervised special survey projects, managed field office, and supervised field crews.

Shandong Eastdawn Corporation

Name: Yasunori Ono

Position: General Manager

Work Experience

1977~ 2004 **AMADA Co. LTD** (Japan).

- Mechanical design of Electric discharge machine.
- Development of Electric discharge machine control software.
- System design of sheet metal processing integration machine
- Development of sheet metal handling system by robotics

2004~2007 **CREA s.r.l** (Italy) Managing director

- System design of sheet metal processing integration machine
- Software development for sheet metal handling robot programming

2007~2009 **AMADA Co.LTD**

- Product planning
- System design of sheet metal processing integration machine

2009~Present

Shangdong Eastdawn Corporation (Jinan/China) General Manager

- Manage of Japanese Data center and International Data Center
- Manage of SEDC Quality control system

Education

1973 ~ 1977 Shizuoka University (Japan) Machine engineering

1985 Union of Japanese Scientists and Engineers

Basic Quality control course

Quality management course

Eastdawn

Tony Sheng, M.Sc. P.Eng.

PROFILE

Tony is responsible for data production and the company's quality management system. He is a senior manager with financial responsibility. With over 9 years' study and work experience in Canada, Tony obtained valuable knowledge of western culture, English language skills, professional engineer work ethics and project management skills. Tony is a Canadian citizen.

EDUCATION

- M.Sc., Department of Geomatics Engineering, University of Calgary
- B.Sc., School of Geodesy and Geomatics, Wuhan University

PROFESSIONAL EXPERIENCE

Shandong Eastdawn Corporation, 2014 – Present Director of Technology & Quality Assurance

- Assist with organizational budget and strategy setup
- Ensuring that proper procedures were in place and followed for delivering quality mapping products and services to customers
- Evaluating the latest technologies for potential implementation in the production processes
- Leading innovation, process improvement and workflow optimization efforts to gain efficiencies in the production procedures
- Maintain and monitoring ISO9001 system inside the organization
- Providing technical support to sales activities

Shandong Eastdawn Corporation, 2012 – 2014 Production Manager

- Managing daily production activities for international data division. Establish performance evaluation system for staff.
- Train and promote technical staff to improve project performances. Projects cover photogrammetry compilation, GIS, orthophoto, 3D modelling and LiDAR classification etc.

Focus Surveys Limited Partnership（Canada）2006 - 2012 Oil & Gas Geomatics | Project Manager

- Managed and oversaw various survey engineering work carried out for Nexen Long Lake Projects. Created tracking records of large and complex projects. Successfully renewed a 3 year new contract with client. Work experience covers:
  - LiDAR planning and evaluation for core hole programs and disposition surveys
  - Corehole surveys
  - Disposition surveys
  - Engineering surveys (construction layout, volume tracking for subcontractors, as built survey etc.)
  - Ground disturbance monitoring and database maintenance
  - Engineering Design for Well Pad construction
  - Traffic Impact Assessment (TIA)

University of Calgary, Department of Geomatics Engineering, 2003 - 2005 TA&RA

- Consulting service for GSD Canada for the environment impact analysis of natural gas exploration in the arctic. Feasibility study for replacing high precision leveling with GPS for deformation monitoring in the arctic.

Topcon Positioning Systems, Inc. (China Branch), 2001 - 2003 GPS Products Support Engineer

AFFILIATION

- The Association of Professional Engineers, Geologists, and Geophysicists of Alberta (APEGGA)

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