



Woolpert PROJECT PLAN #077199 NCTCOG ORTHOIMAGERY

PROJECT PLAN PREPARED BY: ERIC COLE

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WOOLPERT WORK PHASE RESPONSIBILITIES

Aerial Triangulation -	Karl Leibfacher
Image Processing -	Joe Cantz
LiDAR Processing -	Zach Shuler
QA/QC -	Eric Cole
ADS80 Imagery Collect -	Eric Cole
Frame Imagery Collect -	Eric Cole
LiDAR Collect -	Eric Cole
Survey -	Gorrondona
Additional Services -	Sam Moffat
Project Management -	Eric Cole

TABLE OF CONTENTS

Project Overview	Section 1
Project Work Plan	Section 2
Schedule	Section 3
Deliverables	Section 4
Compensation	Section 5
Appendix.....	Attachments - Orthoimagery/LiDAR Flight Maps and Control Diagram

1. PROJECT OVERVIEW

Required Project Task			
x	Survey	x	Metadata
x	Aerial Imagery Acquisition		
x	LiDAR Data Acquisition		
x	Aerial Triangulation		
x	Ortho Processing		
x	LiDAR Processing		

PROJECT OVERVIEW

The North Central Texas Council of Government (NCTCOG) program is a five year contract to perform Photogrammetric, Surveying, and GIS services. The NCTCOG region includes 16 counties consisting of Dallas, Tarrant, Collin, Denton, Rockwall, Kaufman, Wise, Johnson, Hood, Erath, Hunt, Navarro, Ellis, Somervell, Palo Pinto, and Parker, which cover approximately 12,800 square miles.

On a yearly basis, NCTCOG coordinates with local public agencies to determine the need for geo-spatial services. Based on participant interest the project area and project deliverables will be defined each year by NCTCOG and its participants. Each year the flight constraints and deliverables change and it is possible that in some years participation may fall to a level that NCTCOG elects not to provide a collaborative flight under this arrangement.

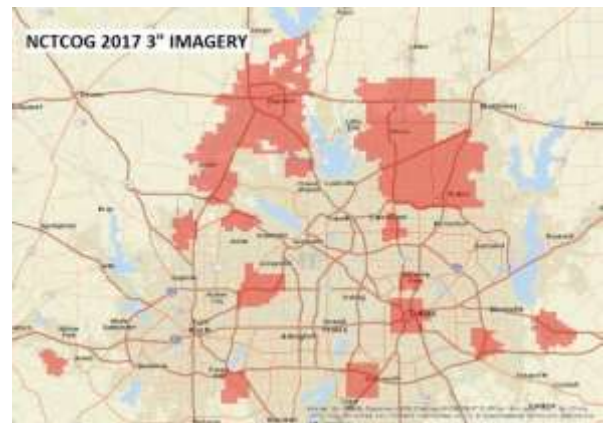
OVERVIEW OF SPECIFIC ELEMENTS OF TECHNICAL APPROACH FOR 2017

Project Area

The project consists of the following project area:

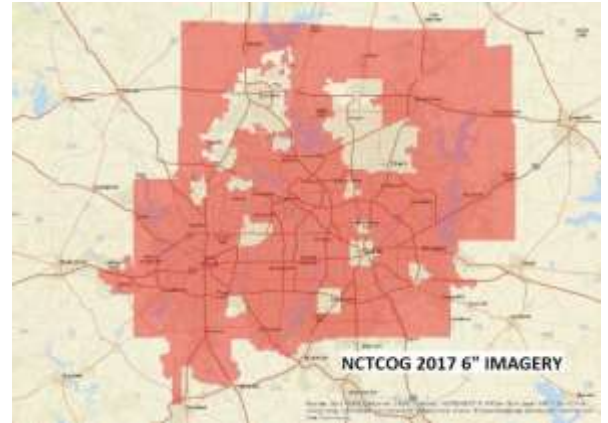
0.25-foot (3-inch) pixel resolution – Frame Imagery

- Microsoft UltraCAM with 100mm lens in non-restricted airspace and 210mm lens in restricted airspace.
- 0.25-foot (3-inch) pixel resolution - 4-Band Digital Orthoimagery
- 597 square miles



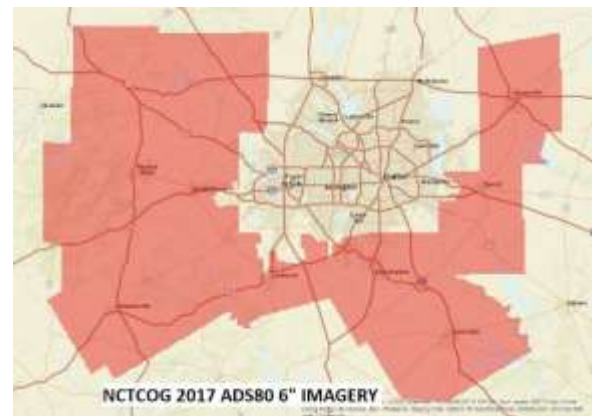
**0.50-foot (6-inch) pixel resolution –
Frame Imagery**

- Microsoft UltraCAM with 100mm lens
- 0.50-foot (6-inch) pixel resolution - 4-Band Digital Orthoimagery
- 3,485 square miles



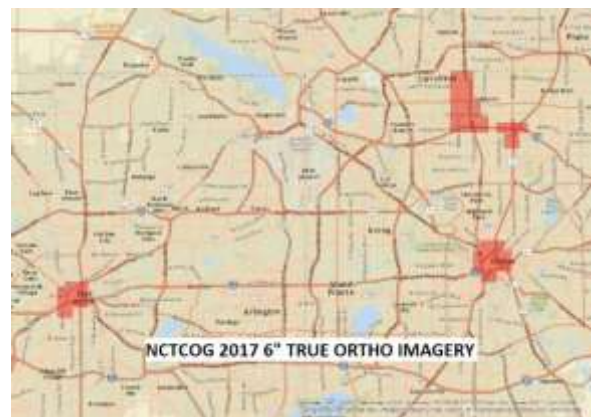
**0.50-foot (6-inch) pixel resolution –
ADS80 Imagery**

- Leica ADS80 Sensor
- 0.50-foot (6-inch) pixel resolution - 4-Band Digital Orthoimagery
- 9,784 square miles



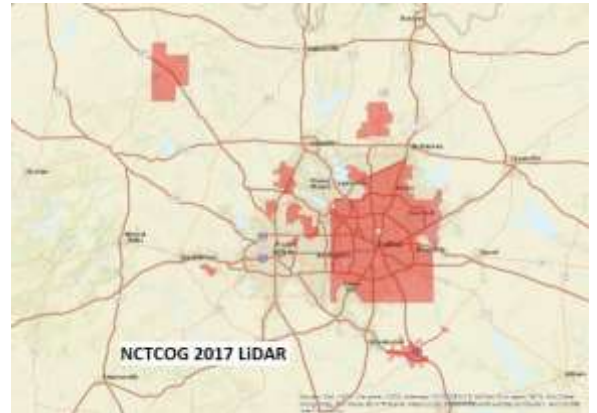
**0.50-foot (6-inch) pixel resolution “True
Ortho” – Frame Imagery**

- Microsoft UltraCAM with 100mm lens
- 0.50-foot (6-inch) pixel resolution - 4-Band Digital Orthoimagery
- 48 square miles



0.5-Meter LiDAR

- Leica ALS70 Airborne LiDAR with USGS v1.2 Specification
- 1,340 square miles



Pilot Area

The pilot area is +/- 2 square miles located within the project area. Woolpert and NCTCOG will determine the appropriate LUT and color balance for the entire 2017 project using the pilot data for one pilot area in Grapevine TX.

Project Datum

The horizontal datum used for this project will be the North American Datum 1983 (NAD83), Texas State Plane Coordinate System, North Central Zone, and expressed in U.S. Survey Feet. The vertical datum used for this survey will be North American Vertical Datum 1988 (NAVD88).

Accuracy

All photogrammetric mapping products will meet or exceed ASPRS Class I Accuracy Standards.

- 1"= 50' scale mapping (GSD = 0.25-foot. Limiting RMS Error = 0.5 ft.)
 - 2000'x3000' Tiff Tiles
- 1"= 100' scale mapping (GSD = 0.5-foot, Limiting RMS Error = 1.0 ft.)
 - 2000'x3000' Tiff Tiles
- LiDAR - 4 points per sq. meter (9.25cm RMSE)
 - 2000'x3000' LiDAR Tiles

Schedule

The project will be initiated in January 2017 and will be completed on or before in September 29, 2017. Below are the production milestones established for this project:

Overall Tasks Schedule

- Project Plan..... January 2017
- Aerial Imagery AcquisitionJanuary/February 2017
- Ground Control..... February 2017

ADS80 Imagery Schedule

- Aerial Triangulation/Image Processing..... February/March 2017
- Pilot (submit 3”/6” samples for color balance) March 2017
- Digital OrthoimageryApril/ June 2017
- Internal QA/QC..... March/June 2017
- Client Review..... June 20, 2017
- Final Completion of ADS80 June 30, 2017

Frame Imagery Schedule

- Aerial Triangulation/Image Processing..... February/March 2017
- Pilot (submit 3”/6” samples for color balance) March 2017
- Digital OrthoimageryJuly/August 2017
- Internal QA/QC..... August/September 2017
- Client Review.....September 15, 2017
- Final Completion of Frame.....September 29, 2017

LiDAR Schedule

- LiDAR AcquisitionJanuary/February 2017
- Ground Control..... January 2017
- Pilot March 2017
- LiDAR ProcessingJuly/August 2017
- Internal QA/QC..... August/September 2017
- Client Review.....September 15, 2017
- Final Completion of LiDARSeptember 29, 2017

2. PROJECT WORKPLAN

GROUND CONTROL PHASE MANAGER: ERIC COLE

DESCRIPTION

Gorrondona & Associates will perform the ground control for the orthoimagery.

Gorrondona will perform the following:

- Provide a control diagram
- Obtain 116 new horizontal and vertical PIDs for Ortho rectification.
- Obtain 56 new control points for LiDAR
- Obtain 33 additional LiDAR checkpoints
- Provide one copy of the Survey report - April 3, 2017

SURVEY AND PLANNING

Along with the use of existing ground control, Woolpert has directed Gorrondona & Associates to obtain new control points as stated above. The new imagery control points will be photo-identifiable points (PID) as often as possible. PID points are more environmentally friendly and avoid unnecessary public intrusion and interference in the community. PID points will be picked on clear, well-defined locations that are photo identifiable from the appropriate scale. The PID points will be semi-permanent such as an X etched in concrete, PK Nail, or 18" rebar with cap.

The new LiDAR control points will be placed on flat unobscured features as defined by Woolpert.

New control points will be GPS observed and be consistent with second order horizontal and third order vertical. This control will be sufficient to meet the required accuracy necessary to support the subsequent orthoimagery and LiDAR datasets.

DATUM

The horizontal datum used for this project will be the North American Datum 1983 (NAD83), Texas State Plane Coordinate System, North Central Zone, and expressed in U.S. Survey Feet. The vertical datum used for this survey will be North American Vertical Datum 1988 (NAVD88).

SURVEY REPORT

The Woolpert Team will provide a Survey report containing all the pertinent information required, such as control diagrams, point descriptions, photographs, log sheets, etc. The report will be consistent with reports submitted by Woolpert. April 3, 2017

CONTROL DIAGRAMS

The survey diagrams are included in this plan and has been delivered to the surveyor (See Appendix).

DELIVERABLES AND QUALITY STANDARDS

The Woolpert Survey team will deliver the following:

- Survey Report - April 3, 2017

The Woolpert Survey team will use the following accuracy standards:

- The ground control accuracy shall satisfy a Local Network accuracy of 5-centimeters at the 95% confidence level.
- New control points will be GPS observed and be consistent with second order horizontal and third order vertical accuracies as defined by the NGS. All control points will be tied to the Dallas/Fort Worth VRS network.

AERIAL IMAGERY ACQUISITION PHASE MANAGER: ERIC COLE

DESCRIPTION

For 2017, Woolpert will obtain new 0.25-foot and 0.50-foot 4-band imagery project wide. The areas dedicated as “Frame” imagery in the client provided shape file will be acquired using a single frame Microsoft UltraCAM camera. The areas dedicated as “ADS80” imagery in the client provided shapefile will be acquired using a Leica ADS80 push broom style camera. All imagery will be captured at a flying height to produce 0.25-foot and 0.50-foot pixel resolution imagery where required.

Woolpert’s goal is to capture imagery at a lesser resolution than the final output of 3-inch and 6-inch pixel resolution so that no resampling is necessary. Woolpert will acquire 6-inch pixel resolution in the restricted area, using the appropriate camera and lens combination.

Woolpert will conference with the FAA at Dallas Fort Worth (DFW) International Airport and with NCTCOG to go over project logistics with FAA, prior the start of project.

The Woolpert Aerial Imagery Team directed by Eric Cole will perform the following:

- Obtain new R,G,B,NIR aerial photography at 3-inch and 6-inch.
- Develop a preliminary and final flight map/control diagram of the project
- Perform any re-flights required to meet the image specifications
- Incorporate Texas CORS stations and set ABGPS stations for the new aerial imagery
- Flight crews will provide image data to the processing department
- Provide the final diagram in shapefile format of the mosaic coverage’s indicating dates of acquisition for each flight
- Provide one copy of the Aerial Photography report - April 3, 2017

The Woolpert team will provide aerial image acquisition services that encompass these steps:

- Image Acquisition Planning and Preparation
- Aerial Imagery Acquisition
- Reflights
- Optional Resolutions

- Image Specifications
- Aerial Photography Report
- Flight Diagrams
- Deliverables and Standards

IMAGE ACQUISITION PLANNING AND PREPARATION

During the winter of 2017 the Acquisition Team will acquire new 4-band (R, G, B, and NIR) aerial imagery covering the entire project area using a combination of the Microsoft UltraCAM and Leica ADS80 digital cameras. The aerial imagery will be captured to produce orthoimagery at 1" = 50' scale with a 3-inch pixel resolution and 1" = 100' scale with a 6-inch pixel resolution.

AERIAL IMAGERY ACQUISITION

All imagery will be collected during the winter / early-Spring flying season (early to late February) during leaf-off conditions for deciduous vegetation in the NCTCOG region. The sun angle shall be 30-degrees or greater, and streams should be within their normal banks, unless otherwise negotiated. Woolpert will submit the flight logs to NCTCOG as part of our acquisition documentation as confirmation of the actual flight date and time. During flight planning and acquisition, a significant effort is made to limit clouds, snow, fog, haze, smoke, or other ground obscuring conditions in the imagery. In no case will the maximum cloud cover exceed 5% per image. Within the immediate areas of power plants or factories, some steam or smoke and/or shadows may be visible on imagery.

Woolpert will provide a flight line diagram for the project area. The Acquisition Team will make every attempt to capture the appropriate project area each flying season, however weather and ground conditions may influence our ability to accomplish the task in its entirety. Woolpert will provide daily weather reports during the acquisition phase of the project. Together Woolpert and NCTCOG will determine the appropriate action if the aerial acquisition task cannot be completed within the window of opportunity due to uncontrollable events such as weather or ground conditions.

ACCESS TO RESTRICTED AIRSPACE

Woolpert understands that NCTCOG the project area has one of the most challenging aerial acquisition environments in the country. Coordination with the FAA and ATC officials during the project kick off process and during the image acquisition will be vital to the success of this project. The Woolpert team has been granted access to the Bravo Airspace and will fly at an appropriate altitude AGL to adhere to the minimum flight height imposed by the DFW ATC.

REFLIGHTS

Woolpert will run the raw imagery data through an initial process immediately after acquisition has been completed to ensure that all program specifications have been met. This allows any necessary re-flights to be accomplished as soon as possible after the date of the original acquisition.

IMAGE SPECIFICATIONS

The following are the image specifications and guidelines:

3-inch Resolution UltraCAM

Output Resolution—3-inch

Flying Altitude— ~4,000-feet AGL

Forward Lap—60% across the project area

Side Lap—30 % across the project area

Climatic Conditions—sufficiently clear sky

Ground Conditions—free from snow, haze, fog, or dust; when streams are within their normal banks;

Sun Angle—greater than 30 degrees

Atmospheric Moisture—less than 5% cloud cover

Tip—will average one-degree or less, Tilt—will average one-degree or less, and Crab—will average three-degrees or less on the project area

Building Lean—supplemental flights

Tone, Brightness, Contrast—provide various image samples for approval prior to full production

6-inch Resolution UltraCAM

Output Resolution—6-inch

Flying Altitude— ~8,000-feet AGL

Forward Lap—60% across the project area

Side Lap—30 % across the project area

Climatic Conditions—sufficiently clear sky

Ground Conditions—free from snow, haze, fog, or dust; when streams are within their normal banks;

Sun Angle—greater than 30 degrees

Atmospheric Moisture—less than 5% cloud cover

Tip—will average one-degree or less, Tilt—will average one-degree or less, and Crab—will average three-degrees or less on the project area

Building Lean—supplemental flights

Tone, Brightness, Contrast—provide various image samples for approval prior to full production

6-inch Resolution ADS80

Output Resolution—6-inch

Flying Altitude— ~8,000-feet AGL

Forward Lap—ADS captures imagery at Nadir

Side Lap—25 % across the project area

Climatic Conditions—sufficiently clear sky

Ground Conditions—free from snow, haze, fog, or dust; when streams are within their normal banks;

Sun Angle—greater than 30 degrees

Atmospheric Moisture—less than 5% cloud cover

Tip—will average one-degree or less, Tilt—will average one-degree or less, and Crab—will average three-degrees or less on the project area

Building Lean—supplemental flights

Tone, Brightness, Contrast—provide various image samples for approval prior to full production

PRELIMINARY (UN-RECTIFIED) IMAGES

Woolpert will provide preliminary imagery within two weeks after acquisition allowing NCTCOG to view and utilize new imagery for applications that can be performed with un-rectified imagery, while the digital orthoimagery is being produced. Imagery will be delivered using SmartView Connect.

AERIAL PHOTOGRAPHY REPORT

Woolpert will provide an Aerial Photography report containing all the pertinent information required such as -flight maps, Flight log, aircraft, weather log, ABGPS, etc.

DELIVERABLES AND QUALITY STANDARDS

Woolpert will deliver the following:

- Aerial Photography Report - April 3, 2017
- ESRI shapefiles of both planned (navigation) and actual (ABGPS) flight lines. The actual flight lines will be provided as mosaicked coverages and contain attribute information showing date, start, and end times information.

The aerial imagery will be able to produce orthoimagery meeting the following horizontal accuracies: ASPRS for 1" =50' scale and ASPRS for 1" =100' scale

- 3-inch pixel +/- 0.5 RMSE
- 6-inch pixel +/- 1.0 RMSE

Functionality of flight to include the ability to extract layers of data, when combined with LiDARgrammetry mapping techniques to produce optional future products:

- Planimetric features: roads, parking, rivers, lakes, vegetation, etc.
- Topographic features: DTM, 2-foot Contours, etc.

IMAGE PROCESSING / AERIAL TRIANGULATION (AT) PHASE MANAGER: KARL LEIBFACHER

DESCRIPTION

Woolpert will perform image processing, along with aerial triangulation to extend and densify the ground control to support the new digital orthoimagery.

The Woolpert image processing team and triangulation will be directed by Karl Leibfacher and will perform the following:

- Obtain imagery from flight crews and begin image processing
- After the imagery has been processed, perform QA/QC of the acquisition imagery strips and frames to verify coverage and quality and review with the acquisition leader and project manager
- If the imagery is deemed unacceptable, provide a plan for recapture of imagery with the acquisition leader and project manager
- Perform image processing QA/QC and review with the phase manager and project manager.
- Using new ground control and ABGPS data perform aerial triangulation on the new 0.25-foot (3- inch) imagery.
- Using new ground control and ABGPS data perform aerial triangulation on the new 0.5-foot (6- inch) imagery.

IMAGE PROCESSING/ TRIANGULATION

For 2017, Woolpert will perform the image processing and aerial triangulation.

Pre-processed imagery, airborne GPS and IMU data, and both paneled or photo identifiable ground control become inputs to the Aerial Triangulation (AT) process. A rigorous and vetted AT is the fundamental production component for achieving final accuracy standards project-wide. The flight design is very influential to a successful AT execution and solution.

DATUM

The horizontal datum used for this project will be the North American Datum 1983 (NAD83), Texas State Plane Coordinate System, North Central Zone, and expressed in U.S. Survey Feet. The vertical datum used for this survey will be North American Vertical Datum 1988 (NAVD88).

QUALITY STANDARDS

Woolpert Triangulation will use the following accuracy standards:

The aerial imagery will be able to produce orthoimagery meeting the following horizontal accuracies:

- 0.25-foot (3-inch) Pixel Resolution (ASPRS Class 1) ± 0.5 -feet RMSE
- 0.5-foot (6-inch) Pixel Resolution (ASPRS Class 1) ± 1.0 -feet RMSE

DIGITAL ORTHOIMAGERY

PHASE MANAGER: JOE CANTZ

Ortho Deliverables			
Tile Information:		Deliverable Pixel Specifications:	
x	Tile Size: 3,000' X 2,000	x	0.075m (0.25')
x	Naming Convention: NCTCOG standard	x	0.15m (0.5')
na	Deliver Partial Tiles at project boundary	na	4'
x	Deliver Full Tiles touching project boundary	na	0.60m (2-foot)
na	Other- Specify:	na	Other- Specify:
Deliverable Format:		Fill Color for Partial Tiles	
x	Tiff/Tiff World file	na	Black
x	GeoTiff	na	White
na	ECW – ER Mapper image	na	Other- Specify:
na	Other- Specify:	x	Full Tiles only
		MISC Deliverables:	
MrSID Compression		x	Ortho Report: Pdf and hard-copy
x	Compression Ratio:18:1	x	Shapefile of Flightlines
na	Per County/AOI	x	Shapefile of Mosaicked Seamlines
x	Per Tile	x	Shapefile of Tile Index
		na	Metadata: Per Tile
		x	Metadata: Per Deliverable Product
		na	Other- Specify:

DESCRIPTION

Woolpert will produce new 8-bit, 4-band stacked color digital orthoimagery at 0.25-foot (3-inch) pixel resolution and 0.5-foot (6-inch), with accurate X, Y ground coordinates, and RGBN scale values from 0 to 255.

The Woolpert Orthoimagery Team directed by Joe Cantz will perform the following:

- NCTCOG will provide digital files containing bridge locations and building footprints to assist in the orthoimagery production.
- Use the existing DEM data for orthoimagery rectification.
- Use the new 4-band 3-inch and 6-inch pixel resolution aerial imagery
- Use the NCTCOG existing tile grid (3,000' X 2,000')
- Imagery contrast, brightness, and tone will be matched before any mosaicking can be initiated. Use an automated/ interactive methodology to perform image mosaicking.
- Mosaic vector line data will be delivered.
- Using the bridge file as a guide, review imagery and modify any imagery that does not meet the required specification.
- Once the imagery has passed the review process, using the appropriate grid tile the individual tile will be extracted and the data will be provided to the cartography department to be QA/QC'd and installed onto the project website.

The Woolpert orthoimagery team will provide Orthoimagery Services that encompasses these steps:

- Image Rectification
- Image Mosaicking and Radiometry
- Image Aesthetics
- Orthoimagery Tiles and Formats
- Image QA/QC
- Deliverable and Standards

IMAGE RECTIFICATION

Woolpert will match the existing DEM data to a photo image through Z/I ImageStation software to create a digital orthoimage. The relevant DEM data will be merged with the orientation parameters and the new digital imagery. A complete differential rectification is carried out with a set of algorithms that remove image displacement due to topographic relief and the tip and tilt of the aircraft at the moment of exposure. Rectification will be done as a batch process. Rectification blocks will be based upon the image acquisition blocks. The resulting digital orthoimages will be 3-inch and 6-inch primary pixel resolution, with accurate X,Y ground coordinates, and RGBN scale values from 0 to 255.

MOSAICKING AND RADIOMETRY

Woolpert will use Orthovista and ZI Orthopro software for tone balancing and image mosaicking. The digital orthophotography will be seamless and have uniform, balanced color. Tiles will be mosaicked so the images appear to be completely seamless, except at mosaic lines on bodies of water. Special attention will be given to the placement of mosaic lines in developed areas so as not to bi-sect buildings, bridges or other man-made structures not at ground level. Woolpert image specialists will take special care around bridges and overpasses to correct excessive distortion. Bridges and overpasses will not appear to be warped or skewed. Overpasses/bridges along roadways shall retain location and geometry. Radiometric adjustment will include color balancing, overall tone adjustment and brightness and contrast enhancements of the imagery over the entire project.

IMAGE AESTHETICS

As part of the image processing procedure, Woolpert will provide a minimum of three different image data sets. Woolpert's image specialist will prepare each data set with various color balance, tone, density, contrast, and brightness qualities. Woolpert will meet with NCTCOG to determine the appropriate image sample to be used as a guideline for the pilot project. During the review of the pilot further refinement of the image settings may take place before implementing full production.

ORTHOIMAGERY TILES AND FORMATS

The orthoimage tiling format will follow a modular layout, with each 1"=50' scale image and 1"=100' scale image covering 3,000' x 2,000' and named according to the NCTCOG naming convention. Orthophoto tiles will be clipped to eliminate overlap between adjacent tiles. Woolpert will use an interactive mosaicking process for tone balancing and image mosaicking. Full tiles will be used within the project interior and full tiles will be used along the exterior perimeter.

VALIDATION AND ORTHOIMAGERY QA/QC

Each digital orthoimage will be checked and corrected to ensure a proper and consistent tone, as well as density, contrast, and brightness qualities. Each image will be checked on the screen at the intended output scale for image defects or other blemishes. Each digital orthoimage will be checked for accuracy on screen. All control points and test points that are visible on the aerial photography are visited on screen and the X, Y coordinates are displayed. This information is cross-referenced with the X, Y information provided by the ground survey. In addition, each orthoimage will be checked against adjacent images at the tile boundaries to ensure that there are no displacement errors.

DELIVERABLES AND QUALITY STANDARDS

The Woolpert Orthoimagery team will deliver the following:

- One set of 4-band stacked digital orthoimagery at 0.25-foot (3-inch) pixel resolution for each tile in GeoTIFF format with TIFF world files
- One set of 4-band stacked digital orthoimagery at 0.5-foot (6-inch) pixel resolution for each tile in GeoTIFF format with TIFF world files.
- ESRI 10.1 shapefile of flightlines with acquisition dates
- ESRI 10.1 shapefile of control points
- ESRI 10.1 shapefile of tile index
- ESRI 10.1 shapefile of mosaicked seamlines
- Each deliverable product will include FGDC metadata

The Woolpert Orthoimagery team will use the following accuracy standards:

The orthoimagery will meet the following horizontal accuracies:

- 0.5-foot (3-inch) Pixel Resolution (ASPRS Class I) ± 0.5 -feet RMSE
- 1.0-foot (6-inch) Pixel Resolution (ASPRS Class I) ± 1.0 -feet RMSE

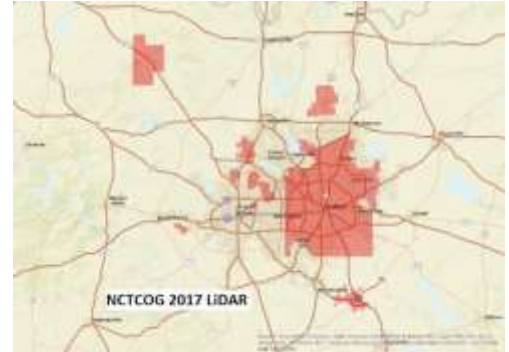
LIDAR ACQUISITION AND PROCESSING

Project Area

The 2017 NCTCOG LiDAR project consists of the following project area-

0.5-meter Airborne LiDAR

- Leica ALS80 Airborne LiDAR with USGS v1.2 Specifications
- 1,340 square



Project Datum

The horizontal datum used for this project will be the North American Datum 1983 (NAD83), Texas State Plane Coordinate System, North Central Zone, and expressed in U.S. Survey Feet.

The vertical datum used for this survey will be North American Vertical Datum 1988 (NAVD88).

Accuracy

0.5-meter LiDAR data will have 9.25cm vertical accuracy based on USGS v1.2 specifications.

The final surface will be capable of supporting 1' or 2' interval contour generation. LiDAR within the restricted airspace will hold an accuracy of 12.5cm, due to the increased flying height.

A total of 20 bare earth/open terrain check shots will be randomly placed within the total 1,332 square mile LiDAR areas.

Metadata

Woolpert will provide metadata compiled at the product set level and conforming to the current Federal Geographic Data Committee (FGDC) standard (FGDC-STD-001-1998) for each of the product sets. The metadata will be USGS parser compliant.

Along with project metadata, Woolpert will provide a shapefile of the image mosaics with dates. This file then can be merged with an image tile file to extract dates for each tile.

Ground Control

Gorrondona will set new control points for the 0.5-meter LiDAR to meet accuracy requirements, 9.25cm vertical accuracy in non-restricted areas and 12.5cm accuracy in restricted airspace areas. All survey tasks will be performed by Texas HUB partner, Gorrondona & Associates, Inc. All control will tie into the TxDOT VRS system.

LiDAR Acquisition

For 2017, Woolpert will be obtaining LiDAR for each AOI, including a minimum buffer of at least 500 feet. If flight clearances are required, we are familiar with the Federal Aviation Administration's procedures for obtaining clearances.

Woolpert will create a flight plan to maximize the capability of the LiDAR system and will obtain data at a nominal pulse spacing (NPS) of 0.5-meters, 4 points per meter. The new LiDAR will be obtained for each task order AOI consisting of point number, X coordinate, Y coordinate and Z coordinate, along with an intensity value.

The flight plan will be developed to take advantage of the AOI geometry to minimize flight time and costs while maintaining high accuracy of the acquired data. The relative accuracy for the LiDAR data will be $\leq 6\text{cm}$ RMSEz within the individual swaths and $\leq 8\text{cm}$ within swath overlap (between adjacent swaths).

The LiDAR data acquisition will occur day or night when no snow is on the ground, rivers are within their channels or below normal levels, when the sky is sufficiently clear of clouds, smoke and atmospheric haze.

Weekly acquisition reports will be provided as shape files. The flight lines will be attributed with the date of acquisition.

Airborne GPS Processing

In this process, kinematic corrections for the aircraft position are resolved using aircraft GPS and static ground GPS (1-Hz) for each geodetic control (Base station) within the task order limits.

IMU Processing

Post processing of the IMU system data is completed to compute an optimally accurate blended navigation solution based on Kalman filtering technology, or the best estimate of trajectory (BET). Typical accuracy achieved through post processing is less than 0.01 degrees for pitch and roll, and better than 0.03 degrees for heading.

LiDAR Point Cloud Processing

When the calibration, data acquisition, and GPS and IMU processing phases are complete, the formal data reduction process will commence as follows:

- Calculate laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. The raw laser point cloud data is created for the entire survey in *.LAS (ASPRS v1.2) format; each point will maintain the corresponding scan angle, return number, intensity and x, y, z information.
- Test relative accuracy using ground classified points per each flight line. We will perform automated line-to-line calibrations for system attitude parameters (pitch, roll and heading) mirror flex (scale) and GPS/IMU drift. Calibration will be performed on ground classified points from paired flight lines. Every flight line will be used for relative accuracy calibration.
- Classify ground and non-ground points. Assess statistical absolute accuracy via direct comparisons of ground classified points to ground RTK survey data. Convert data to orthometric elevations and appropriate map projection.
- Create ground models (DEMs) as triangulated surfaces and export as ERDAS .imp grids at the specific pixel resolution.

The bare-earth LiDAR points will undergo additional QA/QC steps to verify that the artifacts have been removed. Using the bare-earth points determined during the classification, Woolpert will develop a Digital Elevation Model (DEM).

Breakline Compilation Along Water Bodies

This task requires hydrologic flattening of the LiDAR data. Breaklines defining water bodies and stream will be compiled. The breaklines will be used to perform hydrologic flattening of water bodies, and the gradient hydrologic flattening of double line streams. Lakes, reservoirs, and ponds, at a nominal size of two (2) acres or greater (~350' feet in diameter for a round pond), will be compiled as closed polygons. The closed water bodies will be collected at a constant elevation. Rivers, creeks and streams, at a nominal minimal width of 30.5 meters (100-feet), will be compiled in the direction of flow, with both sides of the stream maintaining an equal gradient elevation. Woolpert proposes the following steps to perform the hydrologic flattening of water bodies.

1. Woolpert will use the LiDAR bare-earth data and LiDAR intensity imagery produced as part of this task order.
2. We will utilize the integrated software approach to combine the LiDAR data and 2D breaklines. This process drapes the 2D breakline onto the 3D LiDAR surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edged. The breaklines that characterize the closed water bodies are draped onto the 3D LiDAR surface and assigned a constant elevation at or just below ground level.
3. Lakes, reservoirs and ponds. At a minimum size of 2 acres or greater, will be compiled as closed polygons. During the collection of line work, the technical staff will use staff will use a program that displays the polygon measurement area as a reference to identify lakes larger than 2 acres. Breaklines defining rivers and streams, at a nominal minimum width of 30.5 meters (100-feet), will be draped with both sides of the stream maintaining an equal gradient elevation. All ground points will be reclassified from inside the hydrologic feature polygons to water, class nine (9).
4. All ground points will be classified from within a 1.5 meter (5 foot) buffer along the hydrologic feature breaklines to buffered ground, class ten (10).
5. The LiDAR ground points and hydrologic feature breaklines will be used to generate a new DEM.
6. TerraScan will be used to add the hydrologic breakline vertices and export the lattice models.
7. The new hydrologically flattened DEM will be delivered in 32-bit floating pint rater ERDAS
8. .IMG format at 1 meter pixel, based upon the 1,000 meters x 1,000 meters tiles in the UTM Zone 13, NAD83 projection and NAVD88 meters using the geoid model of 2012 (GEOID12A).
9. The hydrologic breaklines compiled as part of the flattening process will be provided as an ESRI shapefile. The breaklines defining the water bodies greater than 2-acres will be provided as a PolygonZ files. The breakline compiled for the gradient flattening of all rivers and streams at a nominal minimum width of 30.5 meters (100-feet) will be provided as a PolylineZ file.

Quality Assurance and Quality Control

Woolpert's QA/QC workflow is based upon the concept of Macro and Micro level data reviews that will be applied to the LiDAR data to assess for conformance with USGS, NSSDA, and ASPRS specifications. The QA/QC process is based on a structured, sequentially gated process supported by Macro and Micro QA/QC Task Tracking Checklists. The QA/QC review process contains two rounds. The initial review verifies each delivery block in detail per the Macro and Micro checks.

ASPRS Certified Photogrammetrists and Mapping Scientists will review each delivery block and report findings to the production team for resolution and the final review round to validate corrections.

LiDAR Deliverables

Woolpert will provide the following:

- Weekly acquisition reports will be provided as shape files. The flight lines will be attributed with the date of acquisition.
- A final flight line shape files that is attributed with the date of acquisition.
- One digital copy of the ground control and QA/QC points in shape file format.
- One PDF digital copy of the Ground Control Report.
- One PDF digital copy of the Project Report.
- Classified LiDAR data in LAS 1.2 format. Georeference information will be included in the LAS header.
- LiDAR data in ascii format.
- The hydrologic breaklines compiled as part of the flattening process will be provided as a shapefile deliverable.
- One set of 8-bit gray scale intensity images, clipped to match the reference tiling scheme.
- FGDC compliant metadata in XML format.

One set of data for each delivery lot will be provided on external hard drives.

Point Cloud and Bare Earth Data

The point cloud data will be classified and delivered with the following format requirements.

Point Cloud Data will consist of a minimum of first, last, and at least one intermediate return.

- Point cloud data will contain at a minimum
 - X, Y, and Z coordinates
 - Intensity values
 - GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each return.
- Point cloud data will be delivered in a single LAS ½ format file, one for each deliverable tile.
- Point cloud data will be classified according to ASPRS Classification Standards.
 - Class 1 - Default/unclassified
 - Class 2 = Bare earth
 - Class 3 = Low vegetation
 - Class 4 = Medium vegetation
 - Class 5 = High vegetation
 - Class 6 = Building

- Class 7 = All noise
- Class 9 = Water
- Class 17 = Overlap default/unclassified
- Class 18 = Overlap ground

Bare Earth Surface (Raster DEM): A digital elevation model (DEM) will be created and delivered for each delivery tile, with the following specifications:

- To be delivered in 32-bit floating point raster, ERDAS .IMG format.
- DEM will be created from bare earth surface model created during the post processing of the raw point cloud data.
- DEM elevations will be in meters, to two decimal values.
- DEM post positions will be clipped to the appropriate formats. The DEM grids will be at a resolution of (1) meter.
- DEMs will be hydrologically flattened.
- Void areas, such as areas outside the task order AOI boundaries, but within the tiling scheme will be coded using a unique “NODATA” value. This value will be identified in the appropriate location within the file header.
- Data source date: The data source date for the DEMs will be the latest date that LiDAR data is acquired for the given tile.
- Georeference information will be included in each raster file.

Digital Surface Model (DSM)

A first return DSM will be generated to the limits of the buffered project area; however, the accuracy requirements will only be applied to the data within the defined project area. The DSM will be produced with the following specifications:

- To be delivered in 32-bit floating point raster, ERDAS .IMG format.
- DSM elevation will be in meters, to two decimal values.
- DSM post positions will be clipped to the appropriate formats. The DSM grids will be at a resolution of (1) meter.
- Void areas, such as areas outside the task order AOI boundaries, but within the tiling scheme will be coded using a unique “NODATA” value. This value will be identified in the appropriate location within the file header.
- Data source date: The data source date for the DSMs will be the latest date that LiDAR data is acquired for the given tile.
- Georeference information will be included in each raster file.

Metadata

Federal Geographic Data Committee (FGDC) compliant metadata will be provided in extensible markup language (.xml) format for the project. The required LiDAR metadata fields for FGDC compliant metadata, will include at a minimum:

- Date(s) of LiDAR data acquisition.
- Geoid used to reduce satellite derived elevations to orthometric heights.
- Nominal pulse density.

- How GPS coordinates were referenced.
- Maximum and mean differential baseline lengths.
- Calibration procedures, not including proprietary LiDAR data calibration processes.
- Attributes present in the data set (e.g. X, Y, Z, Intensity, all with numbers of significant figures specified).
- Processing steps.
- Positional accuracy including validation of:
 - The point data
 - The bare earth surface
 - Other optional deliverables as appropriate
- Attribution schema description.

A project report will be provided as part of a final delivery lot. At a minimum, the report will include a record of field work procedures, data derivation and adjustments, quality control procedures and results, any problems encountered and solutions used in resolving such problems, and a statistical report summarizing the results of the airborne GPS adjustment and overall accuracy of the adjusted IMU data.

DELTEK PHASE 98— PROJECT MANAGEMENT PHASE MANAGER: ERIC COLE

DESCRIPTION

Eric Cole, will serve as Woolpert’s Project Manager for NCTCOG’s 2017 Digital Orthophotography Project.

Eric Cole will be responsible for the following:

- **Development of the Project Plan.** The project plan is a dynamic document that contains the procedures and documentation on the workflow necessary to meet the final contract specifications.
- **Production of all photogrammetric services as specified in the final contract.** Woolpert will be responsible for the quality, accuracy, and timeliness of all products and services.
- **Maintaining quality control and quality assurance throughout the production cycle to the final products.** Woolpert will implement our ISO 9001:2000 procedures, which are a set of defined and certificated operational guidelines.
- **Delivery of all pilot and final products according to schedule and final contract.** Woolpert will meet with NCTCOG to develop a schedule that works best for all clients involved.
- **Maintaining security of NCTCOG’s source material.** Woolpert will not only maintaining security of the Counties’ source material, but also of all data products acquired and produced through this contract.
- **Identify and disclose any unusual circumstances or issues with datasets.** Woolpert’s Project Manager will be in constant contact with NCTCOG’s representative(s). Through

various forms of communications, Woolpert's PM will communicate any issues or problems to NCTCOG immediately and identify possible solutions to them.

- **Meetings/Briefing Sessions and Reports.** The Woolpert Project Manager will hold bi-weekly Project team meetings. Both internal Woolpert Team meetings and meetings with NCTCOG will be documented with significant decisions and information entered into meeting minutes. Action items will be assigned for follow-up and will be tracked until completed. The results of the follow-up will be recorded and made part of the Project record.

KICKOFF MEETING

A minimum of one briefing sessions will occur face-to-face with NCTCOG representatives. Woolpert will also hold monthly phone conference calls to maintain client communication. The typical number and content are as follows:

Kick Off Meeting and Project Plan Review (1) - February 2017
Pilot Project Delivery and Review (1)
Project Status (1 or as needed)
Project Wrap Up (1)

Eric Cole will tailor the project plan for presentation during a kickoff meeting, which will occur first with Woolpert's production members and then with NCTCOG. An important element of these meetings is the assignment of roles and responsibilities among team members and the client.

After the project manager meets with our production staff, Woolpert will conduct a kickoff meeting with NCTCOG assigned project personnel. In addition to reviewing the negotiated scope of services and roles and responsibilities of team members, the following project components will be identified:

- Any required safety plans (i.e. during survey activities - road/traffic management)
- The required frequency, content, and distribution plan for progress reporting
- Preferred method and frequency of communication between Woolpert and NCTCOG (such as telephone, fax, project website, email, and face-to-face visits)

PROJECT PLAN

Woolpert will meet with NCTCOG representatives to formalize the scope of services into a project plan. During the planning phase, Woolpert will develop a project plan that covers the phases of the project, detailing how to achieve the desired results. Based closely on the negotiated Scope of Services in the contract, this plan will be a step-by-step guide for completing the project. This formal planning phase helps ensure that the final deliverables not only meet the technical specifications outlined in the Request for Proposal, but also the functional needs anticipated by NCTCOG, who will depend on the imagery and related data developed during the project.

PROJECT LOG AND CONFLICT PREVENTION

The Project Manager will be keeping a "Project Issues Log". This is a tool that will allow for a practical method to manage this project by listing key project issues. Everyone knows that almost every project is bound to face issues and problems. Our goal is to identify all those key issues as they happen and list them down in the issue log. Prioritize the issues (using Important and Urgent matrix) and assign the owners with specific deadlines to address them.

TRANSMITTALS

The PM will prepare each transmittal accompanying delivery to the client. Internal deliveries to and from Woolpert offices will be prepared by the appropriate task leaders. All shipments must have a transmittal.

PROGRESS REPORTS, TASK, AND INVOICING

The PM will provide written progress reports and invoices the first of each month. Invoices will be based upon percent complete per task. IOT will issue task orders under the master contract. The task orders will be addendum to the master contract. The following task will be set-up for each year of the contract:

- Project Planning
- Imagery Acquisition
- Ground Control
- Aerial Triangulation
- Orthoimagery

Any additional task will be handled through a contract addendum and added to the project plan.

3. SCHEDULE

The project will be initiated in January 2017 and will be completed on or before in September 29, 2017. Below are the production milestones established for this project:

Overall Tasks Schedule

- Project Plan..... January 2017
- Aerial Imagery AcquisitionJanuary/February 2017
- Ground Control..... February 2017

ADS80 Imagery Schedule

- Aerial Triangulation/Image Processing..... February/March 2017
- Pilot (submit 3”/6” samples for color balance) March 2017
- Digital OrthoimageryApril/ June 2017
- Internal QA/QC..... March/ June 2017
- Client Review..... June 20, 2017
- Final Completion of ADS80 June 30, 2017

Frame Imagery Schedule

- Aerial Triangulation/Image Processing..... February/March 2017
- Pilot (submit 3”/6” samples for color balance) March 2017
- Digital Orthoimagery July/August 2017

- Internal QA/QC..... August/September 2017
- Client Review.....September 15, 2017
- Final Completion of Frame.....September 29, 2017

LiDAR Schedule

- LiDAR AcquisitionJanuary/February 2017
- Ground Control..... January 2017
- Pilot March 2017
- LiDAR ProcessingJuly/August 2017
- Internal QA/QC..... August/September 2017
- Client Review.....September 15, 2017
- Final Completion of LiDARSeptember 29, 2017

4. DELIVERABLES

Woolpert will provide the following:

Ortho Deliverable:

- One hard copy of the Project Plan and one electronic copy in PDF file format (EC)
- One hard copy of the Aerial Image Acquisition Flight Plan and Control Diagram, and one digital copy in shape file format (EC)
- One hard copy of the Aerial Image Acquisition report and one electronic copy of the report in the PDF file format (KL)
- One hard copy of the Survey report and one electronic copy of the report in the PDF file format (G&A)
- One hard copy of the Aerial Triangulation report, and one digital copy in shape file format (KL-ADS) (BM-Frame)
- SmartView Connect On-Line QA/QC Tool (CM and DJ)
- One set of preliminary unrectified images served on SmartView Connect (CM and DJ)
- One set of 1"=50' scale color digital ortho imagery at 0.25-foot pixel resolution for each ortho tile in GeoTIFF format (for 3-inch AOI) (DJ)
- One set of 1"=100' scale color digital ortho imagery at 0.5-foot pixel resolution for each ortho tile in GeoTIFF format (for 6-inch AOI) (DJ)
- MrSID Generation 2 and 4 at an agreed on compression (after final acceptance) (DJ)
- SmartView™ Connect WMS web mapping service (CM)
- FGDC Compliant Metadata (DT)
- Data will be delivered on an external hard drive

Lidar Deliverables:

- Weekly acquisition reports will be provided as shape files. The flight lines will be attributed with the date of acquisition. (EC)
- A final flight line shape files that is attributed with the date of acquisition. (EC)
- One digital copy of the ground control and QA/QC points in shape file format. (EC)
- One PDF digital copy of the Ground Control Report. (G&A)

- One PDF digital copy of the Project Report. (EC)
- Classified LiDAR data in LAS 1.2 format. Georeference information will be included in the LAS header. (ZS)
- LiDAR data in ascii format. (ZS)
- The hydrologic breaklines compiled as part of the flattening process will be provided as a shapefile deliverable. (ZS)
- One set of 8-bit grayscale intensity images, clipped to match the reference tiling scheme. (ZS)
- FGDC compliant metadata in XML format. (DT)

Deliverable Acceptance

The client has thirty (30) days to review each deliverable and submit review comments. Woolpert will review each comment and together with the client determine the appropriate action. If it is determined that Woolpert needs to re-submit a deliverable or portion of a deliverable, that deliverable or portion will be completed and resubmitted within thirty (30) business days after the appropriate action has been determined. Any deliverable not submitted by the Client for review within ninety (90) days will be deemed as accepted; therefore Woolpert will not be obligated to change, correct, or resubmit that deliverable.

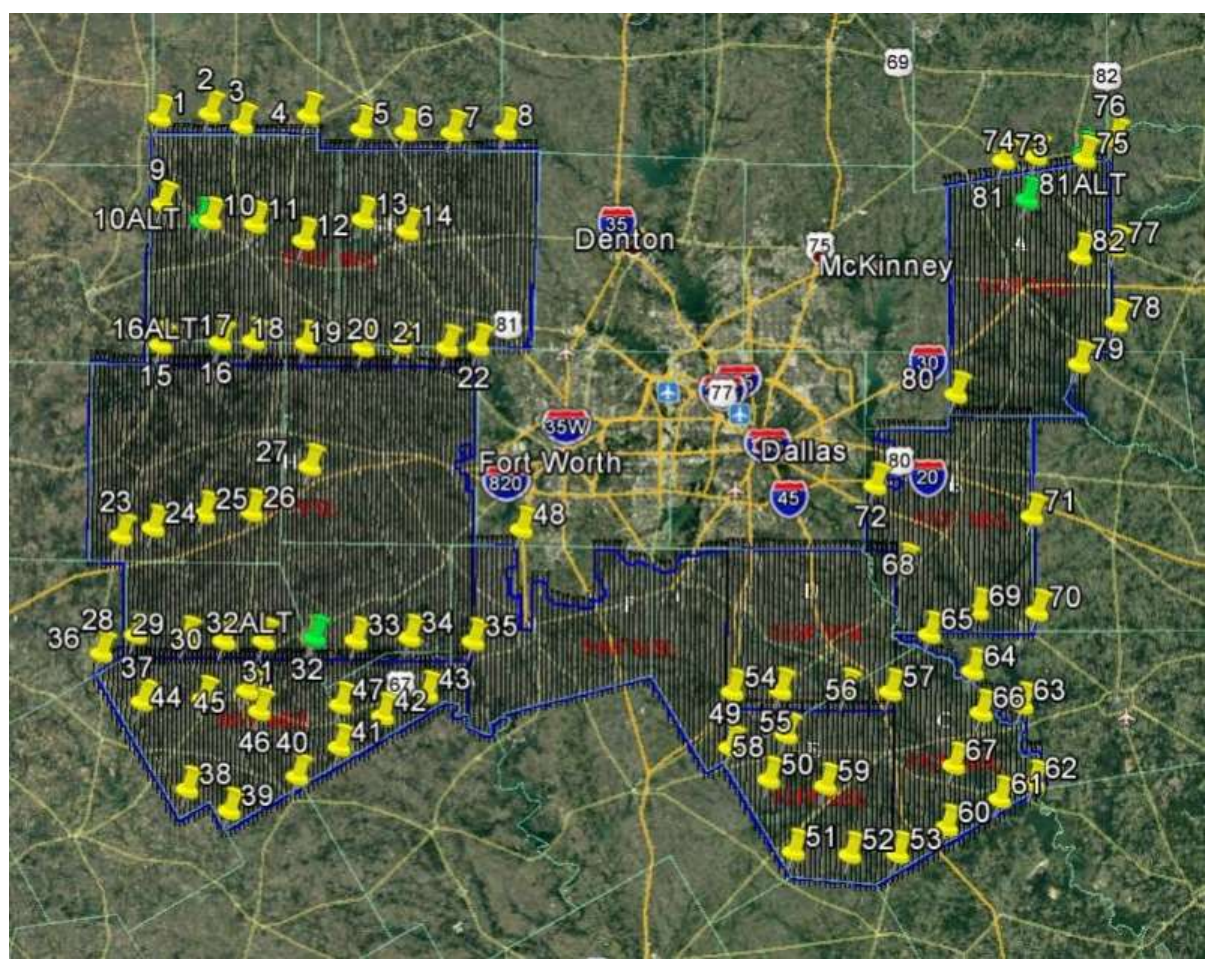
5. COMPENSATION

The fee for services is a lump sum fee. Woolpert will provide progress reports and invoices monthly. Invoices will be based upon percent complete and are to be paid within 30 days after receipt.

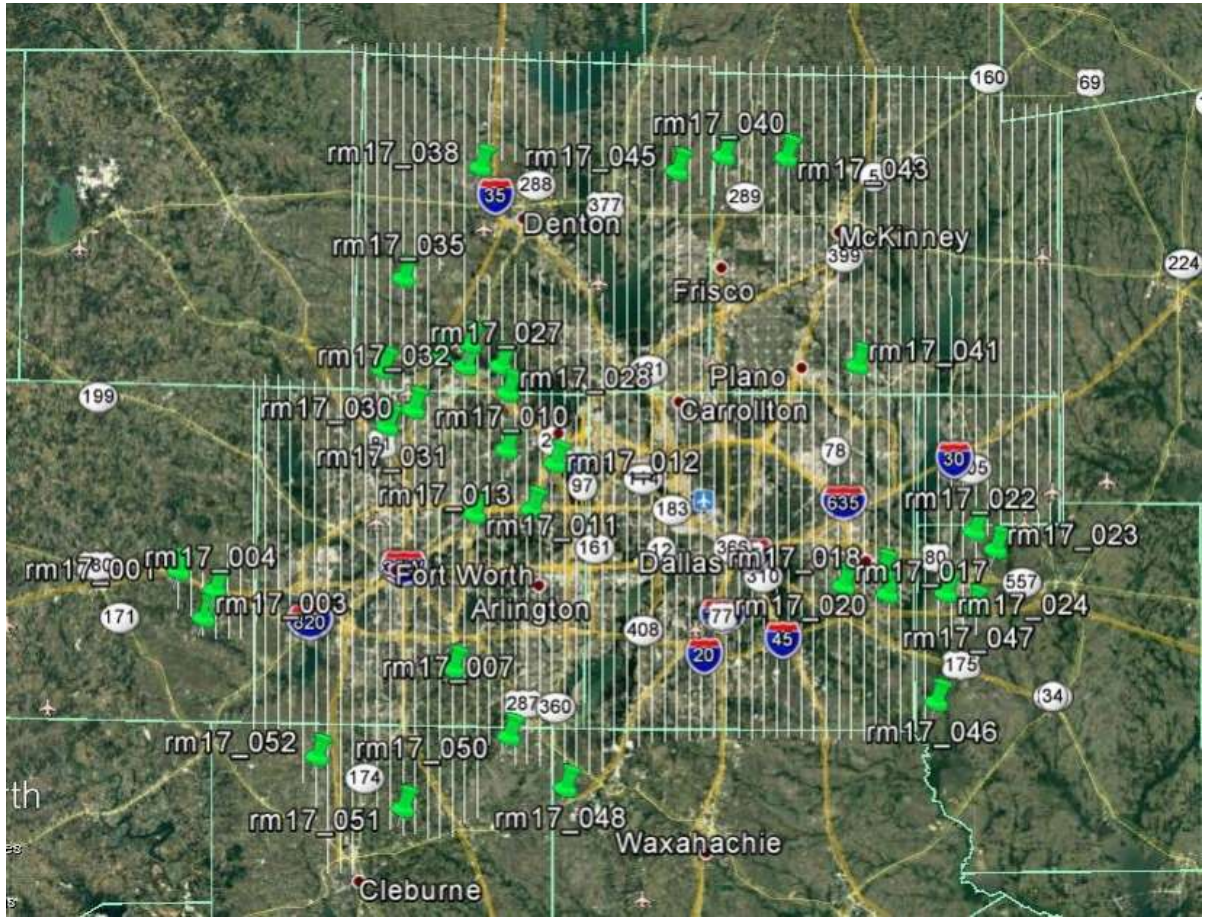
Invoicing will be based upon the following task orders:

1. Imagery Acquisition.....	TBD at Kick-off
2. Ground Control.....	TBD at Kick-off
3. Aerial Triangulation	TBD at Kick-off
4. Orthoimagery.....	TBD at Kick-off
5. SmartView.....	TBD at Kick-off
6. QA/QC.....	TBD at Kick-off
7. Cloud Delivery.....	TBD at Kick-off
8,150.00	
8. Project Management	TBD at Kick-off
Total	\$1,341,444.00

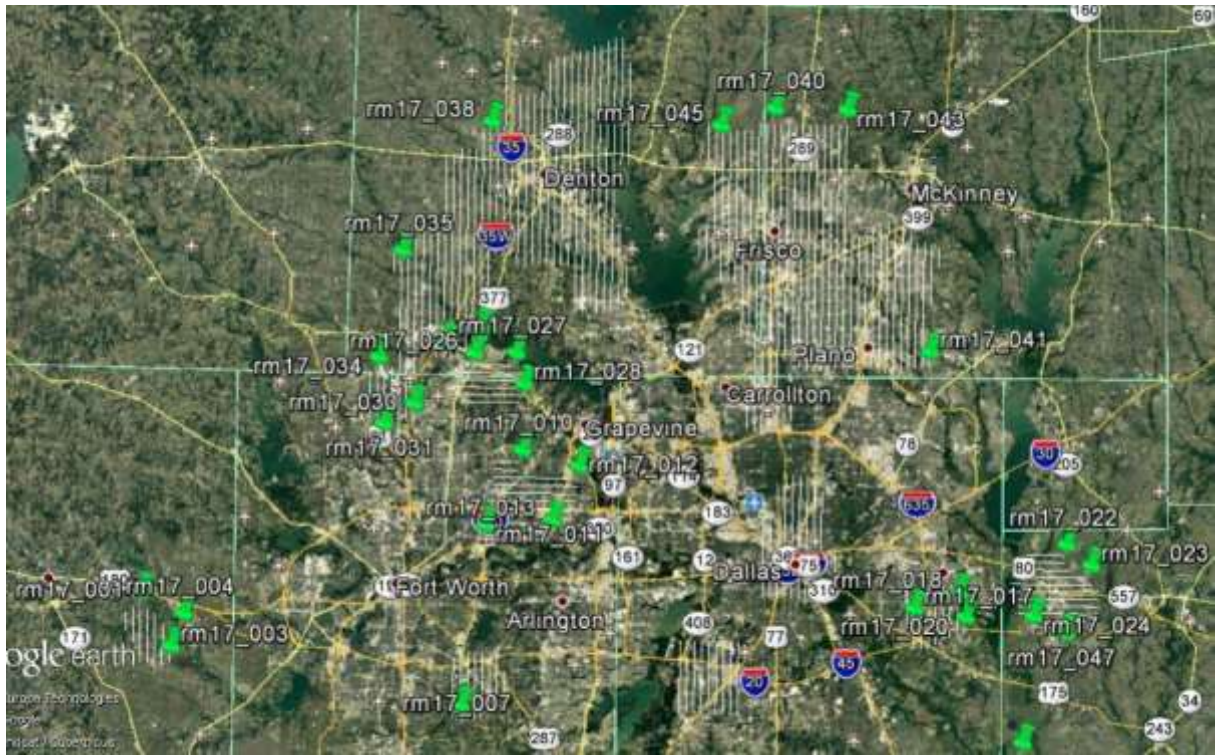
ATTACHMENT "A" ORTHOIMAGERY FLIGHT MAP & CONTROL LAYOUT



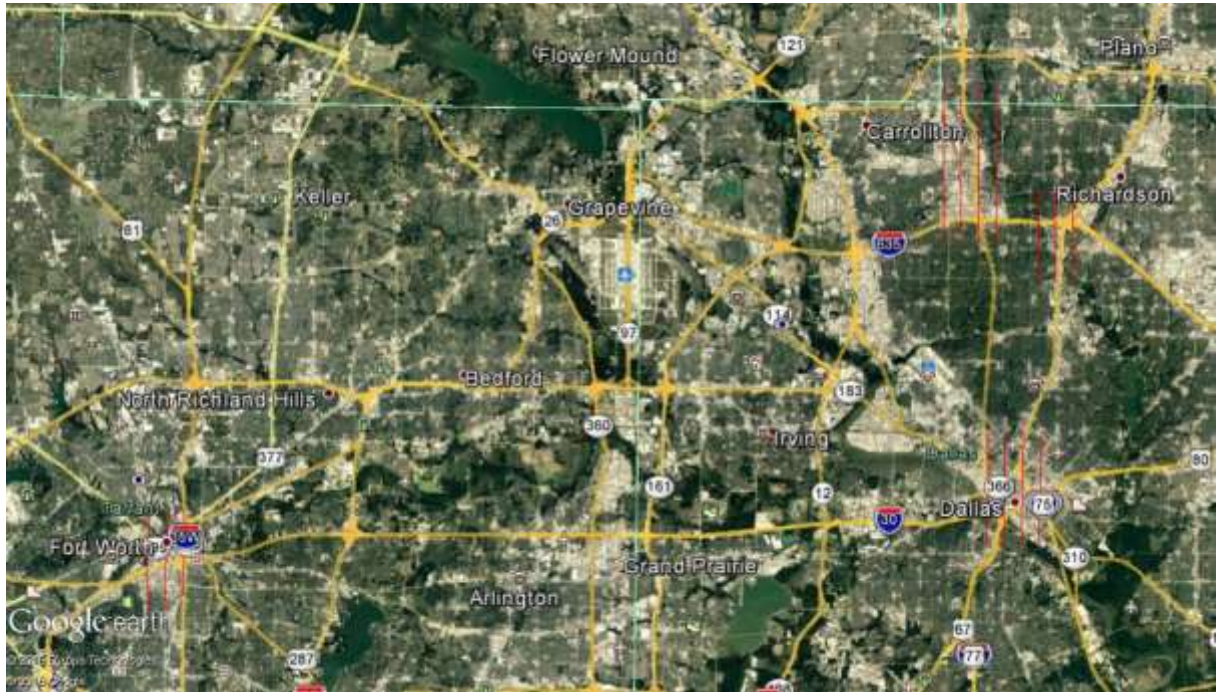
ADS80 Flight and Control



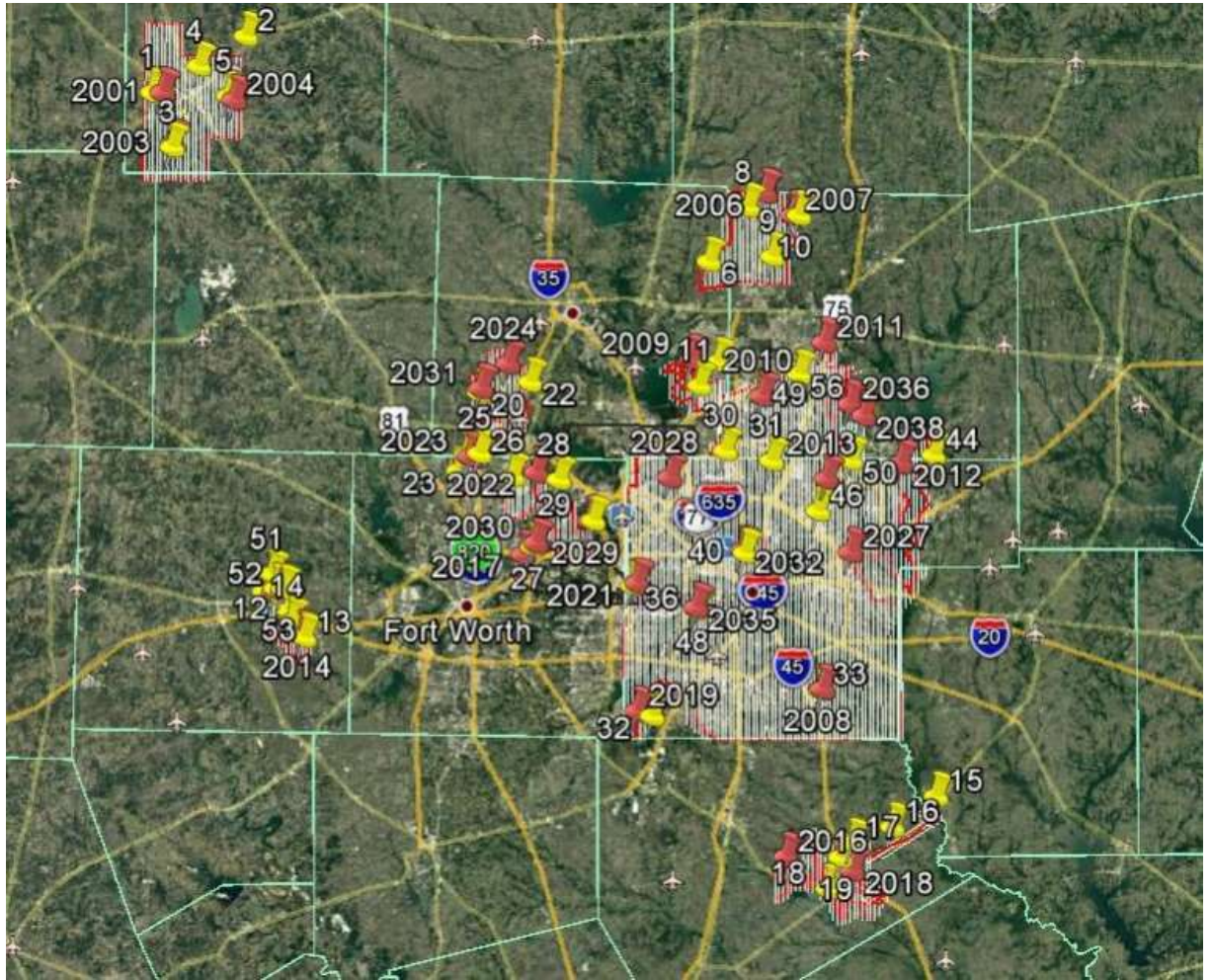
6-inch Frame Flight and Control



3-inch Frame Flight and Control



True Ortho Flight and Control (no new control needed)



LiDAR Flight and Control

