Breaking GROUND

Survey data from the recently completed United States Geological Survey/Leon County 2018-2020 Tallahassee-Leon GIS Landbase Update Project characterizes the area's landscape like never before.

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Leon County, Florida, embodies the "Old South," with acres of natural habitats preserved in the Apalachicola National Forest and the St. Marks Wildlife Areas, old cotton plantations, turpentine producing pine tree plantations, bobwhite hunting and sprawling urban and suburban communities. Located in the thick of Florida's Panhandle, the county includes approximately 225 square miles of natural forest and wetland habitats and an additional 105 square miles of urban Tallahassee. Not far from the city's State Capitol and two state universities, there are tree-lined canopy roads, centuries-old yellow pine flatwoods and saw palmetto, hardwood hammocks and deeply incised ravines, along with magnolias, grandfather live-oak trees and rolling hills.

In 2018, the Leon County Board of County Commissioners, the City of Tallahassee, and the Leon County Property Appraiser's Office — that form the Tallahassee-Leon Geographic Information Systems Department — responded to the US Geological Survey's Broad Area Announcement (BAA) to participate in the nationwide 3D Elevation Program (3DEP). In response to a growing need for high-quality elevation data, the Elevation program will complete the acquisition of nationwide LiDAR (IfSAR in AK) by 2023, providing the first-ever national baseline of

LEFT: Leon County Bottomland Hardwood. ABOVE: LiDAR accuracy is a challenge for Leon County, which is characterized by a densely vegetated land of mixed hardwoods, pine/palmetto flatwoods, upland hardwood hammocks and steep ravines. PHOTOS COURTESY OF GREG MAULDIN, LEON COUNTY GIS PROJECT MANAGER.

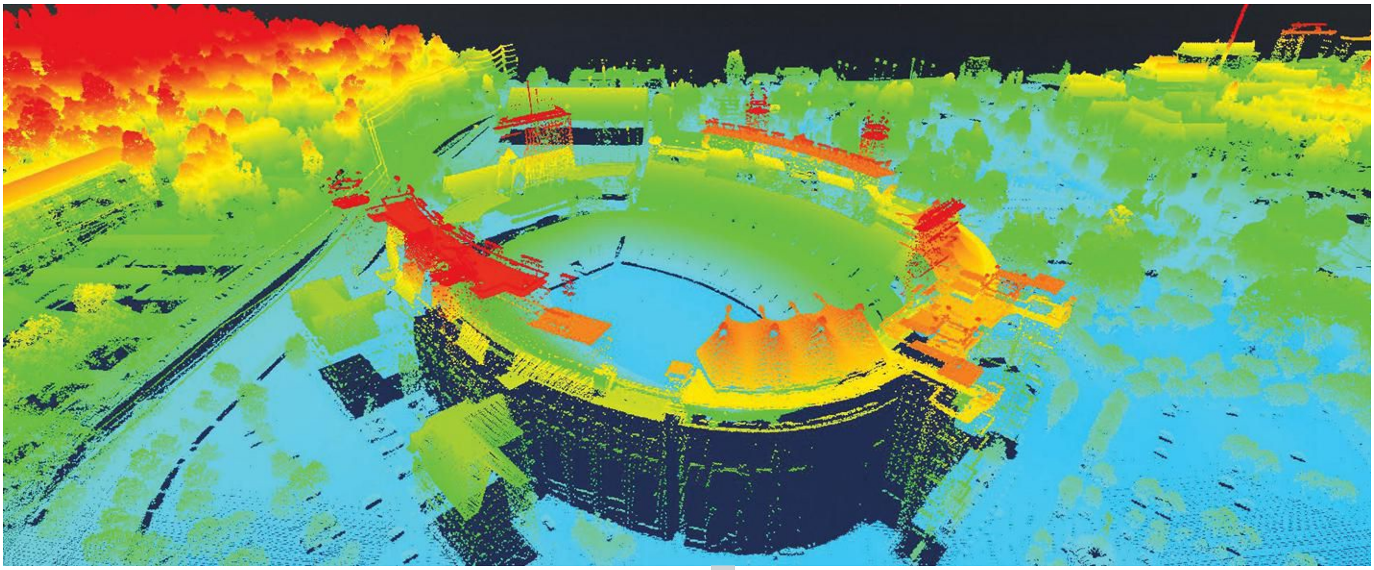
consistent high-resolution topographic elevation data. Federal agencies, state and local governments, tribes, academic institutions and private agencies are encouraged to submit proposals to partner with the USGS or to request funding as the acquiring body of the high-quality 3D elevation data.

For the Tallahassee-Leon Geographic Information Systems Department, the elevation project was an opportunity to obtain high-accuracy survey data that would characterize its varied county landscape like never before. The result is the recently completed United States Geological Survey/Leon County 2018-2020 Tallahassee-Leon GIS Landbase Update Project, a collaboration between the Tallahassee-Leon Geographic Information Systems Department and the USGS through the national survey firm, Dewberry.

PROJECT LAUNCH

The Tallahassee-Leon GIS Landbase Update Project is the most complex LiDAR project that the Tallahassee-Leon Geographic Information Systems Department has ever achieved. A grant from the USGS 3D Elevation Program enabled the department to close a budget shortfall on the project. With extra funding, the department was also able to enlist the help of collaborator in Dewberry — a nationwide firm of planning, design, and construction professionals and contractor in the USGS Geospatial Product and Service Contracts (GPSC), which is used to partner with the USGS for the purpose of fulfilling their geospatial data requirements.

Dense vegetation and a varied urban landscape made accomplishing the accuracy required of high-resolution LiDAR a challenge. During the planning stages of the LiDAR acquisition, several QL0 projects were consulted but all were either corridors or relatively small project areas.



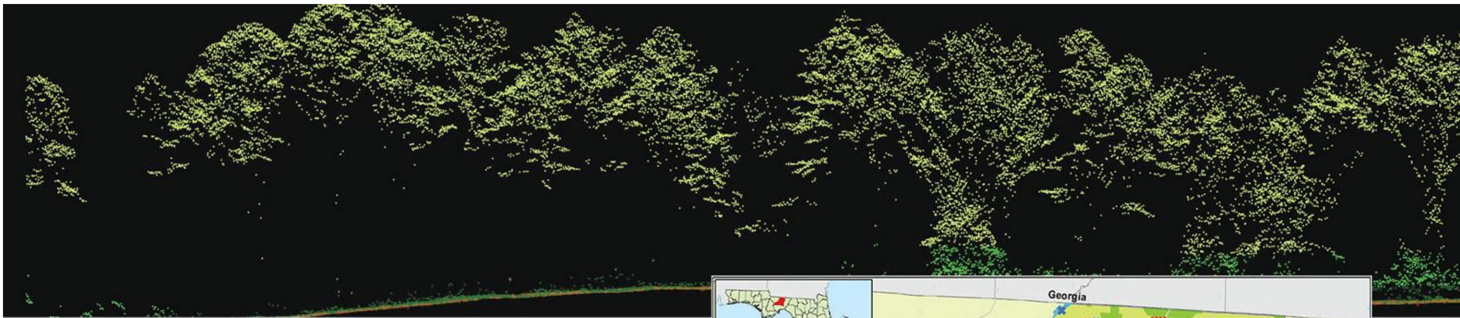
QL0 LiDAR scan of Doak Campbell Stadium in Tallahassee, Florida.

To date, the Tallahassee-Leon Landbase Update is the only example of a county-wide project covering 786 square miles. Although Leon County is only about 700 square miles in area, 779 square miles of LiDAR were acquired to completely fill the 875- 5000' x 5000' tiles (Florida Division of Emergency Management tiling scheme) and a 250-foot buffer around the county. Then, as the county planned on using the LiDAR for multiple purposes, including watershed Hydrological and Hydraulic modeling and planimetric mapping, the county cooperators required USGS LiDAR Base Specification (LBS) Quality Level 0, the most rigorous accuracy specification in the LBS.

Another challenge was having the necessary protocols in place throughout all phases of the project in order to minimize cumulative systematic error during the collection and processing stages to achieve the QL0 quality level. Moreover, there needed to be a way to confirm independently that the non-vegetated vertical accuracy (NVA) and vegetated vertical accuracy (VVA) met the QL0 specifications. This required stringent airborne and ground-based positional control and inertial measurement unit (IMU) measurements. Instrument calibration and boresight processes needed careful handling, and independent checkpoint survey networks had to established to a level of accuracy higher than ever.

What makes Dewberry unique among geospatial contractors is that the firm considers itself "sensor agnostic." Not owning any sensors or aircraft, Dewberry matches the best sensor/airframe to the project. After consulting with all cooperators, Dewberry recommended using a Leica ALS80 LiDAR sensor in a Cessna 421 airframe, flown by Digital Aerial Solutions, LLC (Tampa, Florida) to achieve the high pulse density (<= 8 pulses/m2), high accuracy NVA (<= 5 cm RMSe) and VVA <= 15cm (at the 95th Percentile) LiDAR. Dewberry also recommend that a very strong ground survey component would be necessary to ensure these accuracies.

Following Federal (National Standards for Spatial Data Accuracy: NSSDA) and industry (ASPRS: Accuracy Standards for Digital Geospatial Data) guides, Dewberry designed a ground control point (GCP) and vertical accuracy checkpoint (CP) survey to exceed those guidelines. Checkpoints were evenly distribut-

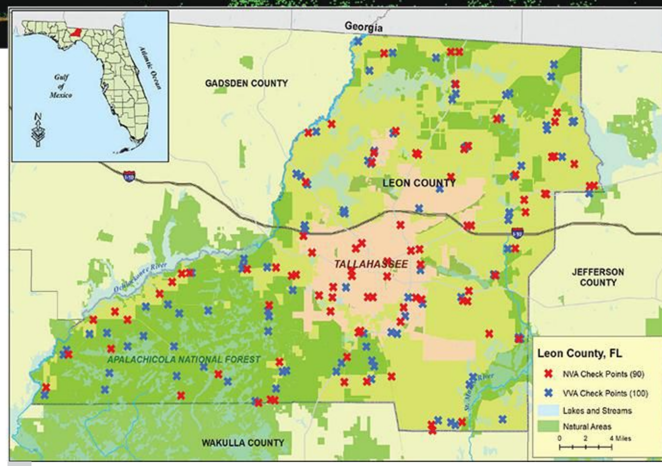


ed throughout the project area to cover as many flight lines as possible using the “dispersed method” of placement.

GROUND SURVEY PROCEDURES

Dewberry surveyors from Panama City familiar with the Leon County landscape performed the ground surveys. Ground surveys were conducted between Feb. 5 and March 9, 2018. Global Position Satellite (GPS) position observations were made with Spectra Precision Epoch 80 GNSS RTK GPS receivers attached to a 2m fixed height pole, together with a Spectra Precision Ranger Data Collector equipped with SurveyPro Sorftware (version 5.2.2). The network design included use of the Trimble VRS Now Permanent Reference Network, a Real Time Network (RTN) managed by the Trimble Company and available throughout the State of Florida.

Because of the high accuracy required by Leon County, Dewberry was especially careful to assess the accuracy of the GPS receivers during the survey. To assess the GPS receivers, 35 National Geodetic Survey (NGS) monuments were recovered and measured during control and ground checkpoint surveys. Root mean square errors (RMSe) were computed for the Northings (RMSen = 0.047’), Eastings (RMSee =0.54’), and Elevation (TMSez =0.06’). A total of 12 existing NGS monuments were located as an additional QA/QC procedure for the purpose of verifying the accuracy of the VRS network. All NGS monuments used are published in



TOP: QL0 LiDAR scan of wooded area in Leon County, Florida. ABOVE: Distribution of Vertical Accuracy Checkpoints (NVA and VVA Checkpoints) surveyed for the Leon County, Florida, High-accuracy LiDAR Mission.

the NSRS database (these formed the primary project control for this survey).

GROUND CONTROL POINT SURVEY

Sixty (60) GCPs were surveyed and 55 of the GCPs were occupied twice. If re-observations matched the initially derived station positions within the allowable tolerance of ± 3cm or within the 95 percent confidence level, then no further occupations were performed. If re-observations did not match the initially derived positions, a static GPS session was collected and processed through NOAA’s Online Positioning User Service (OPUS). Each VRS occupation, using the Trimble VRS Now Network, was occupied for approximately 3 to 6 minutes in duration and measured between 180 - 360 epochs. All static sessions were occupied for a minimum of 45 minutes and up to 100 minutes.

"Dense" is how ground survey crews describe Leon County, Florida. Located in the heart of the Florida Panhandle, the county is teems with approximately 225 square miles of natural, forest and wetland habitats. Included in Tallahassee, an additional 105 square miles of urban Tallahassee. Florida State Capital, two State Universities, tree-lined canopy roads, and old-Florida plantations. Centuries-old yellow pine and palmetto flatwoods, hardwood hammocks and deeply incised ravines, along with magnolias, and grandfather live-oak trees line the scenic canopy roads through the county, and rolling hills characterize the urban, Tallahassee landscape. For obtaining accurate LiDAR data, it is a challenge to say the least.

Most ground control survey data were collected using virtual reference stations (VRS) methodology within a virtual reference system (VRS). However, some survey data was collected using Rapid Static GPS Surveying methodology. Once collected, static sessions were processed through OPUS.

VERTICAL ACCURACY CHECK POINT SURVEY

Methods similar to those used for GCPs also were used for the vertical accuracy Ground checkpoints (CPs). Ninety (90) NVA and 100 VVA vertical accuracy ground checkpoints were GPS-surveyed for use in assessing the LiDAR vertical accuracy. As an internal QC check, 89 of the NVA checkpoint locations, and 96 of the VVA checkpoint locations were occupied twice. If re-observations matched the initially derived station positions within the allowable tolerance of ± 3cm or within the 95 percent confidence level, then no further occupations were performed. If re-observations did not match the initially derived positions, a static GPS session was collected and processed through NOAA's OPUS.

HORIZONTAL ACCURACY CHECK POINT SURVEY

Horizontal accuracy testing requires well-defined checkpoints that can be identified in the LiDAR dataset. Elevation datasets, including LiDAR datasets, do not always contain well-defined checkpoints suitable for horizontal accuracy assessment. However, as the ASPRS guidelines recommend that at least half of the NVA vertical checkpoints should be located at the ends of paint stripes or other point features visible on the LiDAR intensity image, allowing them to double as horizontal checkpoints. Dewberry identified 40 of the checkpoints meet the requirements and were used to assess the horizontal accuracy of the calibrated LiDAR point cloud.

THE LiDAR SURVEY MISSION

The actual LiDAR survey of Leon County was conducted from Feb. 5 to March 2, 2018, using a Leica ALS80 sensor (see specifics in Table 2). The mission covered 875-5000' x 5000' Florida Division of Emergency Management tiles (778.75 square miles) and the county buffer. Data were calibrated and rectified to the North American Datum of 1983 with the 2011 adjustment [NAD83(2011)], and the North American Vertical Datum of

Survey Point Type		Number Required (NSSDA/ASPRS)	NVA	VVA	Total Number Surveyed
Lidar Ground Control Points		60	60	0	60
Accuracy Check Points		170	90	100	190
NVA Classes	Grass/Bare Ground	30	35		
	Aerial Photo Identifiable	50	55		
NNV Vegetation Classes	Short Brush	30		33	
	Tall Brush	30		33	
	Forest	30		34	

Table 1: Control Point and Accuracy Check Point Summary Table. The number of accuracy checkpoints exceeds the NSSDA/ ASPRS recommended minimum number required for testing

1988 (NAVD88). Ellipsoid heights were converted to orthometric heights using GEOID12B. Horizontal and Vertical units were US survey foot.

This project was specified to meet a horizontal accuracy of 1m (3.28 feet) or less at the 95 percent confidence level. Using NSSDA methodology (endorsed by the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)), horizontal accuracy at the 95 percent confidence level (called ACCURACYr) is computed by the formula RMSEr * 1.7308 or RMSExy * 2.448. The Horizontal Accuracy results achieved for the project are given in Table 3. In all cases, the achieved results exceeded the specifications, by more than two-fold and almost three-fold in some cases.

LiDAR POSITIONAL ACCURACY RESULTS

Dewberry quantitatively tested the dataset by testing the vertical accuracy of the LiDAR. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest LiDAR points that constitute the vertices of a three-dimensional triangular face of a Triangular Irregular Network (TIN) of points. Therefore, the end result is that only a small sample of the LiDAR data is actually tested. However, there is an increased level of confidence with LiDAR data due to the relative accuracy.

ITEM	PARAMETER
System	Leica ALS80 HP SN8137 & SN8235
Altitude (Above Ground Level; meters)	3829
Approximate Flight Speed (knots)	155
Scanner Pulse Rate (kHz)	480.0
Scan Frequency (Hz)	61.6
Pulse Duration of the Scanner (nanoseconds)	0.003
Pulse Width of the Scanner (meters)	0.30
Swath Width (meters)	517.48

Table 2: Details of the Leon County LiDAR Acquisition.

Relative accuracy is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement and is verified as part of the initial processing. Dewberry found that (1) the relative accuracy of the dataset was within specifications for QL0 LiDAR (3cm), and (2) the dataset passed vertical accuracy requirements at the location of survey checkpoints. Dewberry concluded that the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy.

	Points Tested		$RMSe_x$	$RMSe_y$	$RMSE_r$	$Accuracy_r$
Horizontal Accuracy		Specification	1.34'	1.34'	1.9'	3.28'
	40	Achieved	0.50	0.44	0.67	1.15

Table 3: Tested Horizontal Accuracy at the 95% Confidence Level.

	Check Points Tested		RMSe$_z$	95% Confidence Level	95th Percentile
NVA		Specification	<=5 cm	<=9.8 cm	
	90	Achieved	3.7 cm	7.3 cm	
VVA		Specification			<=15 cm
	100	Achieved			8.8 cm

Table 4: Vertical Accuracy Achieved for Leon County LiDAR Mission.

For this project, Dewberry used GeoCue-LP360 software to test the swath LiDAR vertical accuracy, Terrascan software to test the classified LiDAR vertical accuracy and Esri ArcMap to test the DEM vertical accuracy. Three different software programs were used to validate the vertical accuracy providing additional confidence in the relative accuracy of the LiDAR data.

For the vertical accuracy assessment, one hundred-ninety (190) checkpoints were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, and forested/fully grown land cover categories. Checkpoints (CPs) were evenly distributed throughout the project area so as to cover as many flight lines as possible using the “dispersed method” of placement (see Figure 2).

Vertical accuracies achieved illustrate the magnitude of the differences between the QA/QC checkpoints and LiDAR data. This shows that the majority of LiDAR elevations were within +/- 0.2 ft (6.1 cm) of the checkpoint elevations, but there were some outliers where LiDAR and checkpoint elevations differed by up to +0.41 ft (12.5 cm).

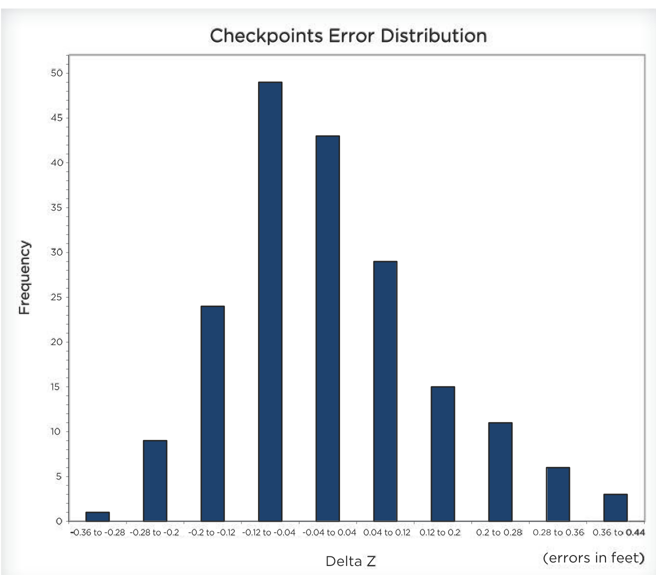


Figure 4: Histogram of Vertical Discrepancies (errors in feet)

The Figure 4 illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the LiDAR triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences.

Based on the vertical accuracy testing conducted by Dewberry, the LiDAR dataset for the Tallahassee-Leon County GIS Landbase Update Project satisfies the project’s pre-defined vertical accuracy criteria. To achieve the high levels of accuracy required for this project, Ground Control and Ground Check Point surveys were carefully designed, additional redundancy and QC was built into the procedures, and conducted with high levels of precision to ensure the accuracy of the final LiDAR products.

Partnering with a firm such as Dewberry, that had the professional skills and the dedication to seeing the project through all the challenges, was the final necessity. Dewberry’s team pulled this off splendidly. The NVA tested to 4 cm RMSEz, exceeding the QL0 base specification of 5 cm by 20 percent. The resulting data completely wowed project stakeholders in terms of fine surface details visible in the DEM and high vertical accuracy, making the Tallahassee-Leon County GIS Landbase Update Project a success for Leon County and the state’s entire aerial mapping community.