SHOW ME THE DATA

Is mobile LiDAR viable as a surveying tool? A surveying and mapping firm puts the technology to the test.

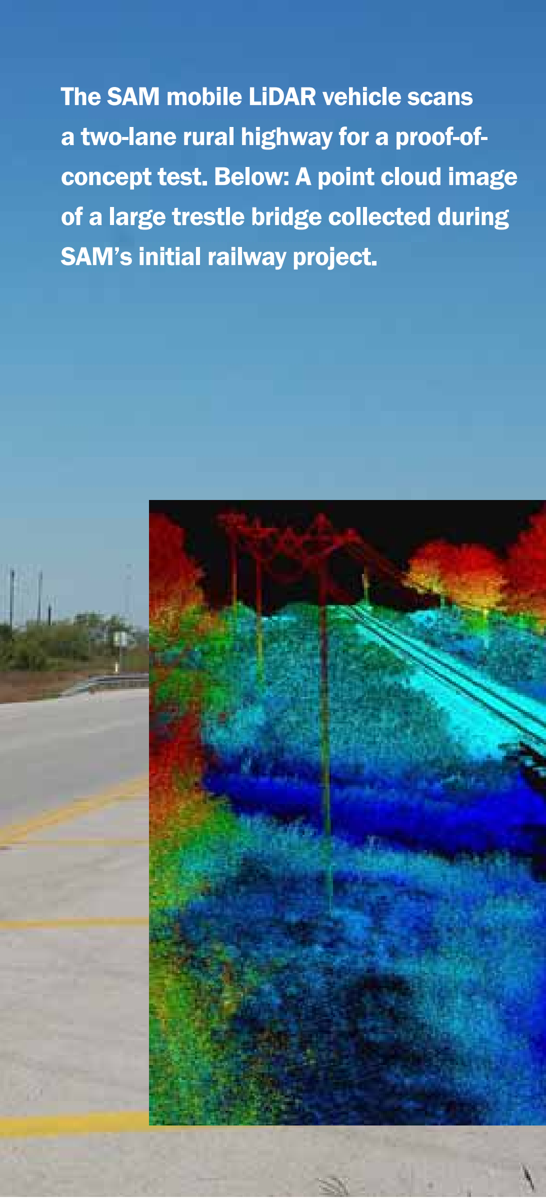
BY S. KEITH McNEASE, RPLS, PS, CP

Since the launch of the first commercial mobile LiDAR systems in 2007, the professional surveying community has been closely following this technology. Equipped with multiple lasers specifically designed for mobile applications, these systems have become well publicized for their ability to capture data as accurately as traditional survey methods in a significantly shorter period of time.

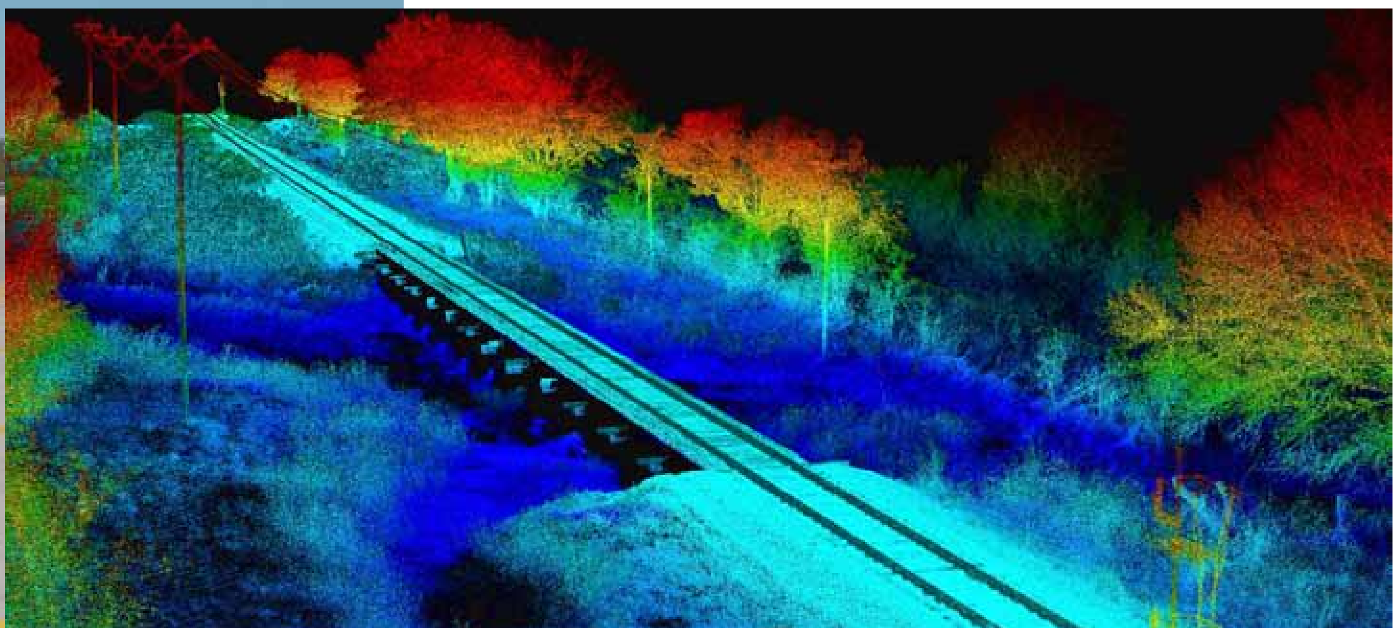
However, skeptics are quick to point out that the relative and absolute system accuracies stated by the device manufacturers are generally based on results achieved through laboratory testing in controlled environments. In fact, a number of questions remain, says Sam Hanna, RPLS, president of Texas-based Surveying And Mapping Inc. (SAM Inc.). "For those in the surveying business," he notes, "the big questions are: Can we get survey grade results in a real-world situation with this technology? What is the actual attainable accuracy of the system? Are the results repeatable? And can we trust the data?"

By most accounts, mapping/GIS-grade positional accuracies are readily achievable with the onboard GPS and position orientation system (POS) integrated into the mobile LiDAR system, but this level of control alone will not support typical design survey requirements of less than 0.1-foot accuracy.

Hanna, whose business philosophy has centered around recruiting the best people and providing the most advanced equipment and training, recognized the potential of mobile LiDAR early on. After carefully studying the technology and the experiences of some of the earliest adopters, Hanna was ready to take the leap. SAM purchased an Optech Lynx Mobile Mapper system in September 2009. The firm then undertook two proof-of-concept projects using the new system. "We wanted to develop some real-life examples that would help clients understand that mobile LiDAR technology could be used as a survey tool," Hanna says. "And we wanted to determine what best practices should be employed to achieve accurate results on a repeatable basis."



The SAM mobile LiDAR vehicle scans a two-lane rural highway for a proof-of-concept test. Below: A point cloud image of a large trestle bridge collected during SAM's initial railway project.



Proof of Concept No. 1: In the Fast Lane

The first project was a resurvey of a 3-mile-long section of a two-lane rural highway that SAM had previously surveyed using GPS and traditional methods. The firm had also collected aerial mapping data along the roadway corridor. The goal was to prove that mobile LiDAR could achieve survey-grade positional accuracies on a busy roadway with minimal traffic disruption. The datasets previously produced would serve as a baseline for data-accuracy comparisons. After hearing about the potential capabilities of mobile LiDAR, the client was on board to conduct the test.

Based on their experience with GPS and airborne data collection, the SAM team decided that the GPS and IMU data onboard the mobile mapping system would need to be supplemented with high-order ground control if there was going to be any possibility of achieving survey-grade accuracies. The team relied on its past work developing control layouts for aerial mapping and terrestrial scanning projects as well as its aerial triangulation and GPS knowledge to configure different ground-control scenarios for the highway project.

To establish the primary control, the field crew set up Trimble R8 base stations to create a geometric figure that encompassed the project area. The crew also repainted the previously established aerial mapping targets with a highly reflective paint, which is specifically designed for highway projects, to ensure that the targets would be readily identifiable within the point cloud data. Targets were located approximately 1,500 feet apart on alternating sides of the road.

The SAM crew then collected data along the entire project with the mobile LiDAR system running two passes in the northbound direction and two passes in the southbound direction. Due to traffic and posted speed limits, the data-collection vehicle operated at approximately 30 mph while collecting the data, which yielded a raw point density of 6,000 points per square meter. The crew also ran two passes in the eastbound and westbound directions of the intersecting highways that defined the north and south project limits.

Once the data acquisition was complete, the crew headed back to the office where the monumental task of downloading, backing-up and processing the data began. Using disk extract software, the SAM team downloaded the data from the removable 300 gigabyte SCSI drives. The data included the laser range data and raw image picture files (the mobile mapping system is equipped with two 5-megapixel cameras that collect continual images at three frames per second). Raw trajectory data were also downloaded from the system operation laptop.

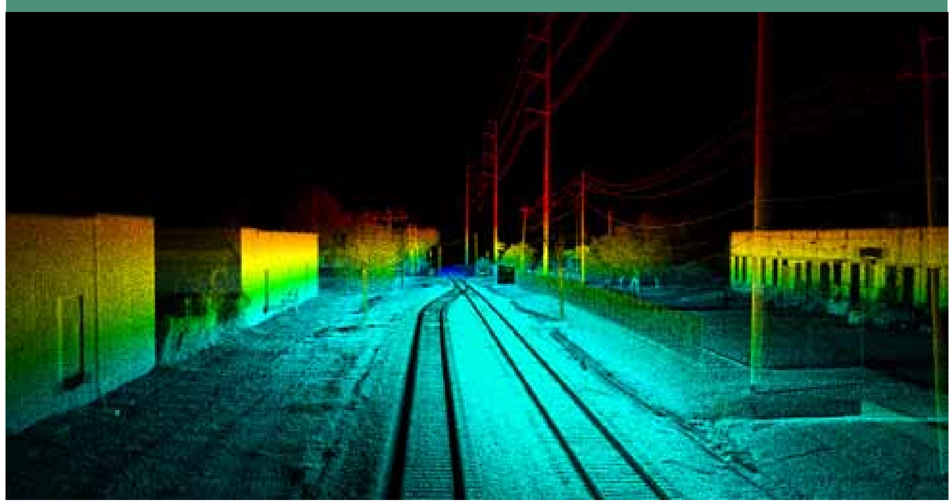
With the downloading complete, the SAM team began data processing. "We wanted to make sure that we were creating a controlled environment," says Ruben Gaztambide, RPLS, SAM project manager. "So we reprocessed the base station data and verified the accuracy of the coordinates on which we were going to build our project. Satisfied, we then proceeded with the original published values."

This work was done using Applanix's POSPac MMS (Mobile Mapping Suite) software. As part of the process, SAM included GPS data collected at four GPS base stations along with the Applanix SmartBase solution, which used the geometric configuration and geographic positions of the base stations to solve for atmospheric distortion errors and to provide a tighter solution.

With the smoothed best estimate of trajectory (SBET) computed, the SAM team moved on to the processing of the laser (LAS) file. Using Optech's DASHMap software, which geospatially references the laser data to the trajectory through a time relationship, the LAS files were calibrated to ground-control targets.

To ensure they had created a good control environment, the technical staff processed the control targets using a Trimble

Left: The SAM mobile LiDAR hi-rail vehicle travels through a commuter station during its first full rail project. Below: The mobile LiDAR unit scans a section of railway, also picking up transmission lines along the track right-of-way.



R8 GNSS RTK solution and the DOT/NGS RT3 (real-time Class 3) standard. As an additional test control, the SAM team ran digital levels using a Leica DNA10 to elevate the aerial targets to verify good vertical solutions for ground control.

Once the team members were satisfied with the results, they continued processing the scan data using GeoCue Corp.'s Lynx MMS CuePac software to organize and manage the files and Terrasolid's TerraMatch software to tie the laser scan data to the ground-control data for improved geometric accuracy. "Throughout all of these different iterations, we measured and recorded the differences between the check points and the scan cloud," Gaztambide says. "We performed statistical calculations to produce a root mean square error (RMSE) horizontally as well as vertically. With the differences being 0.01 foot or less, we were satisfied that our control environment would meet or exceed the client's expectations."

After the TerraMatch process was completed, the team chose identifiable positions from the point cloud that would be field checked and used those positions to conduct a quality control accuracy assessment. The team selected 30 points distributed across the project and then collected x, y and z values, which were used to determine positional accuracies. The team collected the points adhering to the DOT/NGS RT3 GPS standards and ran digital levels for an independent check on vertical positions.

With validated coordinate values on the check points, SAM evaluated the results by statistical means of calculating RMSE values and attained a horizontal RMSE value of 0.06 foot and a vertical RMSE value of 0.08 foot. This error was within DOT sur vey/design standards and proved that survey-grade data are fully achievable. "Using this process, we were able to conduct a side-by-side comparison of the tested achievable accuracies of the system against a design quality survey dataset, which had been previously collected through traditional survey methods," says Gordon Perry, RPLS, Mobile LiDAR department manager for SAM. "The tests were designed to help us develop best practices for our Mobile LiDAR department, and that's exactly what we did."

Proof of Concept No. 2: Right on Track

The SAM team's next task was to provide proof-of-concept verification for railway applications. "Our past rail experience told us that mobile LiDAR would be a great tool for mapping grade data in a single pass in open areas as well as over bridges and through tunnels," Perry says. Again, the firm wanted real-world data to prove the theory.

A survey of a 2.25-mile section of a freight and commuter rail line turned out to be the ideal evaluation project. The client wanted to design a two-way rail siding that would allow the passage of trains in both directions simultaneously. The company had previous experience with SAM and believed that the firm's mobile LiDAR technology would be the perfect way to acquire the necessary rail data.

The SAM team began planning the project as soon as it received the primary system control from the client. The team first chose three of the primary control points that were within the project area. Along with these

Right: A SAM mobile mapping tech processes mobile LiDAR data using Terrasolid softwar. Below: A point cloud image of a railway passing underneath a major highway overpass system.

three points, two additional points were selected to create a good geometric figure that would encompass the project location.

The mobile LiDAR crew coordinated with the rail operator to gain track-side access to paint control targets along the railway. Targets were placed approximately every 500 feet to ensure that a high positional accuracy could be achieved. "While the project area was limited to only 2.25 miles, during our scheduled track access, we had permission to run the entire 32 miles of present track," Gaztambide says. "We ran it both ways for a total of 65 miles of data acquisition, including sidings."

The entire data acquisition process took 10 hours, which included time waiting at switches and crossings and for the clearance of zones occupied by train system fieldworkers and others. "Following the data acquisition, we began downloading and backing up the data," Gaztambide says. "With track access being a very difficult endeavor, backing up the raw data files was vital to guarantee data protection."

The team used control metadata to rebuild the original primary control network. The primary control was resurveyed and adjusted to CORS and projected to the Texas State Plane Coordinate System using Trimble Business Center software.

With the coordinate values established, the team confirmed the quality of the primary control data. Then, as with the highway project, SAM technicians processed the SBET and LAS data to build the Terrasolid model. The dataset was approximately 800 gigabytes, but GeoCue's software allowed SAM to push the data through in a few days using one of its large multiprocessor servers specifically designed to build the project. "If you were to push this volume of data through a traditional workstation, it would likely crash," Perry says. "If it didn't, you should expect it to take several weeks to complete the processing."

Following the initial data extraction and processing, the survey crew again gained access to the railroad so they could determine x, y and z coordinate values for the ground control. Crew members also collected random check points while in the right-of-way in order to have a baseline to compare the quality of their data.

After that task was completed, they began the TerraMatch process. With the dense control scenario employed and minimal differences between the unadjusted point clouds, only a few hundredths of a foot worth of adjustment was needed to meet the ground control. After evaluating the quality control check points and quantifying their accuracies, SAM achieved a horizontal RMSE value of approximately 0.04 foot and a vertical RMSE of 0.06 foot. With these results, the team was confident that their data were well within design survey specifications.

A Viable Tool for Data Collection

Armed with the latest in survey/mapping technology, SAM set out to prove that mobile LiDAR data could be used to produce past experiences with GPS, terrestrial scanning and aerial mapping/LiDAR surveys, SAM was able to plan and execute two very different projects using mobile LiDAR for data acquisition. The team members confirmed that survey-grade positions were attainable with the integration of sufficient project control into the positional solution for the point cloud datasets, and they created standards to ensure this outcome on future projects. "By utilizing a properly controlled project site, we are able to achieve absolute horizontal and vertical positional accuracies of less than 0.1 of a foot," Perry says. "We have documented how we achieved these results and can demonstrate that mobile LiDAR is a viable solution for many large-scale surveying projects as a survey-grade tool."

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