# The Use of Innovative Data Collection Techniques in Support of Enterprise Wide GIS Development

ARTHUR J. LEMBO, JR., PhD, CHRISTOPHER POWERS, PE, AND EVAN S. GORIN

**Numerous authors have indicated that the use of scanning airborne laser systems are effective in performing rapid and accurate mapping for engineering purposes (Gutelius, 1998; Reed, Landry, and Werther, 1996; Reed and Lynch, 1996; Reed, Lapucha, Werther, and Rosenbalm, 1994; Lapucha and Barker, 1996). Recently, this technology has been employed by the Long Island Rail Road in support of an enterprise-wide geographic information system (GIS).**

## Background

The Long Island Rail Road (LIRR) services over 266,000 commuters each day throughout their 600 miles of track. In addition, the railroad performs numerous tasks related to track maintenance, facility maintenance, communications, power, and public safety.

The purpose of the LIRR GIS Database Development project was to create a geographic information system (GIS) database containing as much information as practical and beneficial about the LIRR's facilities and infrastructure. The system is designed and implemented to serve as the railroad's enterprise-wide GIS. Future activities will result in the development of applications using the GIS that will support activities and requirements of the departments within the LIRR.

Tasks under the GIS Database Development project included:

- Data Collection
- Requirements Definition
- Pilot Project Implementation

In order to accomplish this work, the LIRR developed a *Request for Proposals* that outlined the requirements for the project. Upon review of competitive proposals, the LIRR chose Bowne Management Systems, Inc. of Mineola, NY and their sub consultants: John E. Chance and Associates, Inc. of Lafayette, LA, and Applied Geographics of Boston, MA to implement the project.

### GOALS AND OBJECTIVES

The objective of the project was to create a Geographic Information System (GIS) land base consisting of approximately 330 miles of existing passenger rail facilities owned and operated by the Long Island Rail Road on Long Island, New York. In order to accomplish the work, the LIRR developed specific goals for its completion. The goals of the project included the following:

- The ability to reference the GIS land base to NYS State Plane System NAD 83 (North American Datum 1983) and NAVD 88 (North American Vertical Datum 1988).
- The ability to collect LIRR assets with a horizontal and vertical accuracy of 1'.
- No interruption of any LIRR operations.
- No LIRR flagman support.

### PROJECT SCHEDULE

The LIRR sought to complete the collection of data within 3 to 6 months. The reason for the fast schedule was to accommodate numerous projects that would require GIS data. Some of the projects included a long range track and signal strategy, a tie replacement program, a system-wide conditional survey, and the development of an automated work order management system.

## Methods

The LIRR data requirements, in addition to the schedule, required an innovative technique to complete the data collection task within the budget and schedule supported by the LIRR. Upon investigation of the different options available, Bowne and the LIRR chose to use an air-based laser mapping system to collect the data.

Bowne's subcontractor, John E. Chance & Associates, performed the task of data collection. The survey was accomplished along the rail centerline and extended a minimum of seventy-five feet on either side for the defined route. The survey was performed so that individual features could be identified, extracted, and positioned by Bowne for use in developing the GIS land base.

### DATA COLLECTION SYSTEM

The data collection system shown in Figure 1, integrated an accurate GPS positioning system with video imaging and a scanning reflectorless laser rangefinder to provide fast and accurate aerial surveys. The system, aboard a specially equipped Schweizer 300C helicopter, flew over the LIRR corridor collecting precise GPS, platform altitude, laser ranges, and imagery data. With a data collection rate of 8,000 ranges per second, height above ground of 50-70 meters, and an aircraft velocity of 45 miles per hour, the data density was approximately one beam per 1.5 sq. feet. This data density was required to differentiate objects such as rails, mile posts, signals, switches, and subtle changes in slope/grade, etc. by recognizing patterns of points with spatial relationships.

**Positioning System**

The system utilized four rover GPS receivers, Trimble Dual Frequency 4000 SSE's in the aircraft and ground reference GPS receivers. An OMNISTAR™ satellite receiver was used to generate standard RTCM-104 differential corrections from a network of reference stations. With the differential corrections, one of the rover GPS receivers provided the differentially corrected position of the aircraft within sub-meter accuracy for real-time pilot navigation.

All GPS receivers, both rover and ground reference, recorded the dual frequency carrier phase and pseudo range measurements from each satellite. The four airborne rover receivers provided a means for calculating an accurate aircraft attitude, as well as providing a redundancy check on the post processed OTF KGPS aircraft position.

**Attitude System**

The attitude system was comprised of a Humphery vertical gyro to measure instantaneous pitch and roll and was combined with the rover carrier phase GPS data to determine the accurate attitude of the aircraft. The vertical reference unit data, along with the laser data, was recorded during flight by the laser data recorder onto a removable hard disk.

IMAGE COURTESY OF JOHN E. CHANCE AND ASSOCIATES

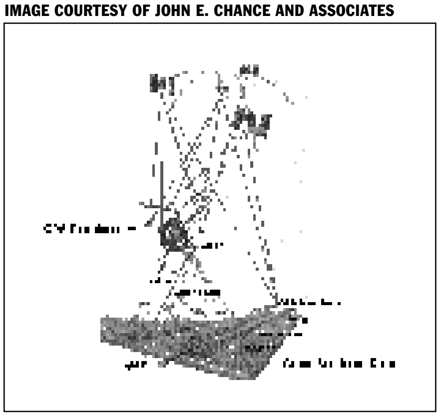

**FIGURE 1.** **Conceptual view of Fast Laser Image Mapping and Profile (FLI-MAP) system utilized by John E. Chance and Associates to collect data for the Long Island Rail Road.**

**Laser System**

The scanning laser utilized a custom designed eye safe, reflectorless rangefinder capable of measuring first return ranges from 20 to 200 meters. Every scan had a width of 60 degrees and contained 200 range measurements. Each scan record contained timing, laser attitude, and data verification/error detection information. Operationally, the laser scanned at a rate of 40 times per second and had a coverage width that was approximately equal to the aircraft's altitude above ground (in this case, 50 to 70 meters).

**Display and Acquisition System**

The system directed the pilot along predetermined survey flight lines, using LED light bars to indicate both horizontal and vertical course deviations. During the flight, the pilot and operator could view both the down-looking and forward-looking video on a flat screen color display. The operator utilized a traditional computer monitor and keyboard for control and status monitoring.

The computer power behind the airborne processing system is multiple Intel-based PCs, which provide airborne data management, sensor control, and navigation processing. Using a removable disk, the data management system records information such as GPS pseudo range and carrier data, laser scan records, and the real-time differential GPS positions.

**FIGURE 2.** **GPS Equipped helicopter used to collect laser imagery and videos for the Long Island Rail Road.**

**Aircraft Integration**

The equipment was integrated in a Schweizer 300C helicopter (Figure 2), which provided a trailerable and cost-effective survey platform. A key design goal of the system was minimal size, weight, and power, allowing for the use of a small inexpensive aircraft. The characteristics of this aircraft allowed uninterrupted data collection of GPS data that was critical for the kinematic positioning.

**Positioning and Accuracy**

Dual frequency OTF kinematic offered horizontal and vertical antenna positions with accuracies of 0.2' at 95% confidence. This method of positioning measured the relativity of the primary rover GPS receiver from occupied local control stations (also 4000 SSE receivers) along the route using kinematic or carrier phase differencing techniques. The dual frequency OTF capability allowed reliable ambiguity initialization while the helicopter was in motion in a matter of seconds. For reliability and quality control, reference stations were spaced along the route approximately every ten to fifteen miles.

The absolute accuracy of collected ground and feature data using OTF kinematic positioning was 0.5' horizontally and 0.35' vertically. The relative accuracy of data points collected with subsequent scans and to the kinematic control network is 0.35' horizontally and 0.25' vertically. The relative accuracy of points common to a single scan is 0.2'.

**FEATURE EXTRACTION**

The laser imagery was processed in the FLIP7© software system, developed by John E. Chance and Associates, Inc. The FLIP7 software system allowed the operators to view the railroad data in both a planimetric and profile view (see Figures 3 and 4). In addition, SVHS videos of the areas were time

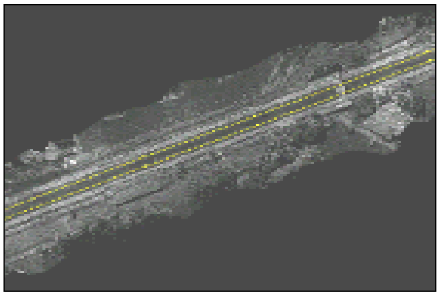

**FIGURE 3. Planimetric view of laser imagery for Smithtown train station, with a vectorized track centerline.**

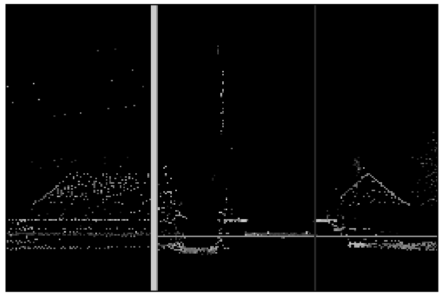

**FIGURE 4. Profile view of laser imagery for the Smithtown train station.**

tagged to the laser location. The videos included both a forward looking and downward looking view of the area on the laser image. Utilizing the video images was very important, as the laser images were often difficult to interpret, especially for smaller objects.

### Locating Discrete Points

As shown in the previous figures, many of the features were easily discernable off of the laser imagery. As shown in Figure 4, the laser imagery was even able to discern the sagging wires between poles, in addition to the steel rails on the track. As one can also see from Figure 4, more prominent features are easy to locate, such as the station platform, the station building, and the stairs leading up to the platforms.

As previously mentioned, the laser image representation of this data is accurate to .5' horizontally and .35' vertically. To collect the discrete features as a vector representation for use in the LIRR GIS, operators simply performed a "heads up" digitizing of the points and "connected the dots".

An example of the vector output from the digitizing is shown in Figure 5.

## Results

#### QUALITY CONTROL

Quality control checks were performed to verify the accuracy of the digitized features. The methods for performing the quality control were to check the digitized data with the existing Nassau County photogrammetrically derived digital basemap, and to perform field data inspection using GPS technology.

An overlay of the Nassau County GIS planimetric basemap showed a good cartographic fit between the two data sources (Figure 6).

In addition to viewing the LIRR data in conjunction with the Nassau

County data, Bowne performed quality control on a number of discrete points utilizing a Trimble 4000 SSI and a Wild TC1000 REC total station.

The GPS field test check discrete objects such as light poles and corners of platforms. Bowne field technicians utilized the Trimble 4000 SSI to establish local base stations at LIRR station facilities. By establishing the base stations, field crews were able to utilize the Wild TC1000 REC total station to traverse selected locations. The X,Y, and Z coordinates of the surveyed points were compared to the digitized points from the FLI-MAP system. In most cases, the errors were less than .5' in both vertical and horizontal positions.

#### DATA COLLECTION

Due to high winds, fog, inclement weather, and scheduling difficulties with local airports (Kennedy and LaGuardia), John E. Chance and Associates was unable to fly for more than two consecutive days. However, the entire LIRR ROW required only seven full days to complete.

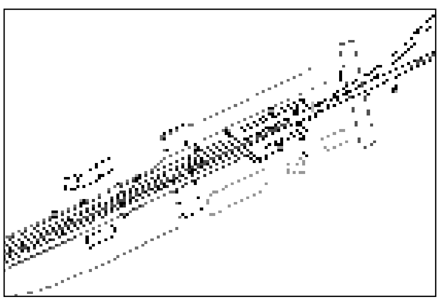

**FIGURE 5. Vectorized version of the Mineola train station showing track centerlines, 3rd rail, buildings, poles, platforms, crossing gates, switches, pedestrian overpasses, and parking facilities.**

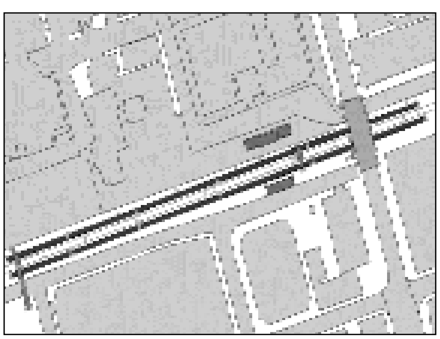

**FIGURE 6. LIRR data on top of the Nassau County photogrammetrically derived basemap.**

#### FEATURE EXTRACTION

Because the laser imagery collected from the helicopter was already in the correct geographic position, Bowne was able to digitize the track centerline for the entire LIRR service area within three man months. The fast rate of production was possible because the operator required virtually no setup time to begin the digitizing. In addition, collecting the data was simply a matter of connecting laser points representing the discrete objects in the field.

Collection of all features within a 20 mile pilot area required three man weeks to complete. During this phase of the data collection it was found that certain features were more difficult to collect. The most difficult features to collect were light poles, or small features such as switch mechanisms. The reason for the difficulty was directly related to the operator's ability to locate the object on the laser imagery. Due to the nature of the first return laser, and the spacing of laser points, a few laser points may have only intersected a 25' pole. The reason for this is due to obstructions such as branches, or the thickness of the pole being less than the laser point spacing. Therefore, the pole may not have stood out well among other features such as trees. In some of these cases, the GPS field survey indicated that the errors due to the operator's inability to ascertain the true location of the point were greater than 1'.

## Conclusion

The Long Island Rail Road GIS Database Creation project demonstrated the ability to accurately and cost effectively map railroad features through the use of a scanning airborne laser system. The project showed that the data collection could occur without any interruption of railroad services. The laser imaging and ranging sensors integrated with the accurate position and attitude sensors provided the railroad with direct mapping capabilities. In addition, the project was not impeded by the time of year. The flying height of the helicopter and use of a fast imaging laser allowed the data to be collected during the month of January.

## References

Gutelius, 1998. "Engineering Applications of Airborne Scanning Lasers: Reports from the Field". *Photogrammetric Engineering and Remote Sensing*. Volume LXIV, Number 4. April 1998.

Lupucha and Barker, 1996. "Dual Baseline Real-Time OTF Kinematic GPS" *In Proceedings of ION-GPS 96*, Kansas City, Missouri.

Reed and Lynch, 1996. "Near Field Airborne Remote Sensing Using a Laser Mapping System on Electric Transmission Line Corridor Surveys and Capacity Analyses". *In Proceedings of The Second International Airborne Remote Sensing Conference and Exhibition*, San Francisco, CA, June 24-27, 1996.

Reed, Landry, Werther, 1996. "The Application of Air and Ground Based Laser Mapping Systems to Transmission Line Corridor Surveys". In *Proceedings of the Position Location and Navigation Symposium (PLANS'96)*, Atlanta, GA.

Reed, Lapucha, Werther, and Rosenbalm, 1994. "An Application of On-The-Fly Kinematic GPS to an Airborne Laser Terrain Profiling and Imaging System", In *Proceedings of the 7th International Technical Meeting of The Satellite Division of The Institute of Navigation*, ION-GPS 94, Salt Lake City, Utah, September 20-23, 1994.

ABOUT THE AUTHORS

**Arthur J. Lembo, Jr.** is a Senior GIS Analyst at Bowne Management Systems, Inc. **Christoper Powers** is the GIS Manager for the Long Island Rail Road. **Evan Gorin** is a Senior GIS Analyst at Bowne Management Systems, Inc.

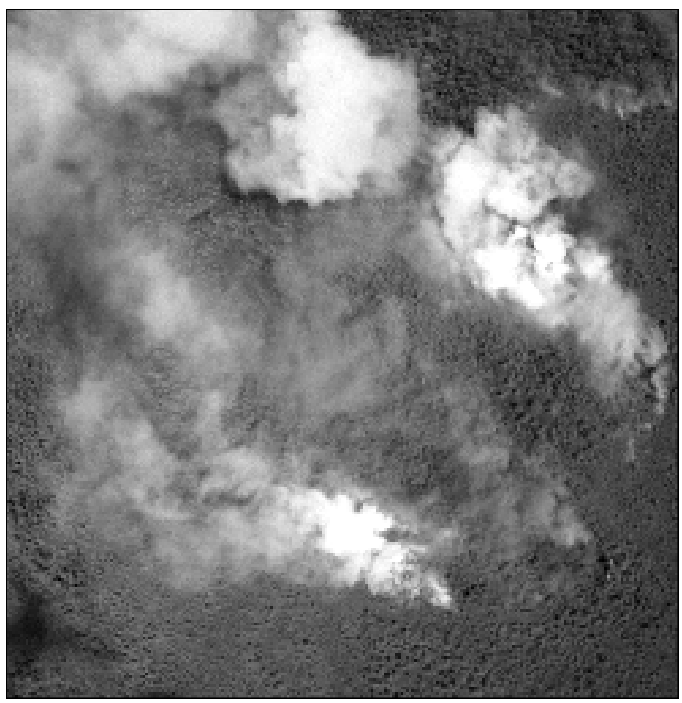

FIGURE 1. This image of the recent, devastating fires in Florida was shot with Litton's Emerge Spatial (E-Spatial) data collection system. View the original CIR in color at the E-spatial web site <http://espatial.wsicorp.com: 2903>.

KIMBERLY A. TILLEY