USING MOBILE LIDAR TO SURVEY A RAILWAY LINE FOR ASSET INVENTORY

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ABSTRACT

This paper discusses the deployment and results of a recent rail line survey for the purpose of conducting an asset inventory of rail side hardware and engineering design work. The study area involved the use of the Lynx Mobile Mapper to collect mobile terrestrial lidar data along a section of a commuter / freight rail in Austin, Texas. The section of rail in question is known locally as the “Red Line”. The project involved the collection and inventory of 32 route miles of track, including sidings and rail yards. The data was processed in DASHMap and TerraSolid. The data was adjusted to conform to control by using the TerraSolid module, TerraMatch. Ground truthing was performed to verify the adjustment made by TerraMatch. Residuals of 0.04 feet horizontally, and 0.06 feet vertically, were computed.

INTRODUCTION

Tracking and evaluating rail side assets has been an ongoing challenge. Surveying for design engineering work has also been a separate, but equally necessary task. Until now, collecting this type of data has been done by field crews, using tripod-mounted survey equipment. Not only is this method slow, but it also exposes surveying personnel to potential hazards and causes a disruption to the operation of the rail line. Fortunately, the growing use of mobile terrestrial lidar mapping is providing a faster, safer alternative to surveying with ground-based, tripod-mounted equipment.

Investigations into the use of mobile mapping systems for the purpose of asset inventory and engineering design work are currently being conducted (Leslar, 2009), (Kremer, 2007), (Haala, 2008). A recent trial was conducted by SAM Inc., in cooperation with the Austin Texas Transportation Authority. A section of the public rail line, known as the Red Line, running from downtown Austin, north to Leander, was surveyed. Figure 1 shows the entire 32-mile route of the Red Line, and its relationship to the city of Austin.

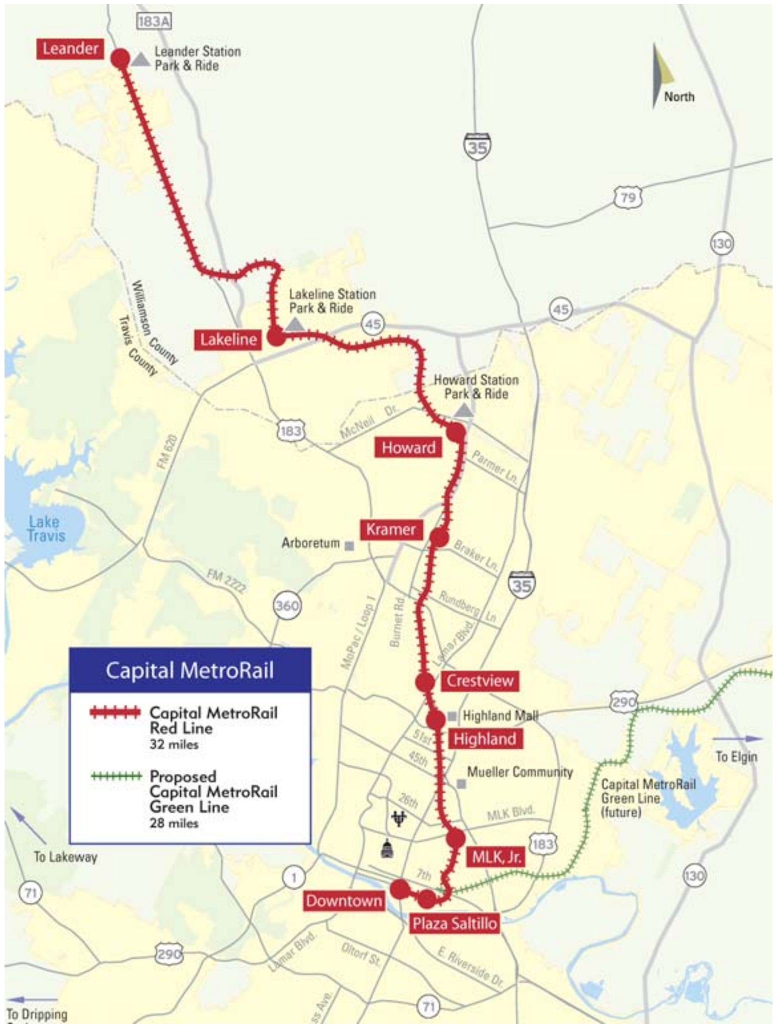

Figure 1. Austin, Texas Red Line rail transit corridor.

The Lynx Mobile Mapper

The mobile terrestrial lidar system used in this study was the Lynx Mobile Mapper, manufactured by Optech Incorporated. The Lynx Mobile Mapper is capable of collecting rich survey-grade lidar and image data from a vehicle moving at traffic speeds. The system is fully adaptable and can be mounted on a variety of vehicles and vehicle types. The system can be configured to use one or two lidar sensors and up to two, 2-megapixel (or 5-megapixel) cameras. The user-programmable lidar scanners can operate in 75 kHz, 100 kHz or 200 kHz mode. The cameras capture images at rates of up to 5 frames per second (FPS) for the 2-megapixel camera, or 3 FPS for the 5-megapixel camera.

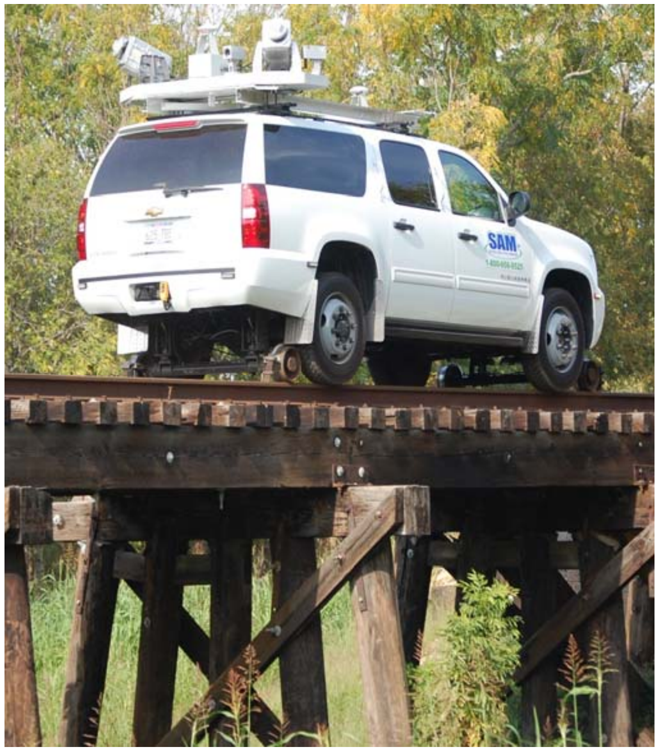

Figure 2. The Lynx Mobile Mapper on a Chevrolet Suburban adapted for hyrail operation.
(Image courtesy of SAM Inc.)

For the purposes of this study, the Lynx Mobile Mapper used two lidar sensors, each collecting at a rate of 200 kHz. Two 5-megapixel cameras were also integrated into the Lynx. These cameras were triggered at a rate of 3 FPS throughout the survey. An Applanix LV420 Position and Orientation System (POS), utilizing an LN200 Inertial Measurement Unit (IMU), was incorporated into the Lynx, and provided trajectory information for the sensor data.

THE SURVEY

Pre-planning

Survey operations began by surrounding the design engineering collection area with four GPS base stations. These stations, combined with GPS data obtained through the Continuously Operating Reference Station (CORS), run by the National Oceanographic and Atmospheric Administration (NOAA), were setup to create a Virtual Reference Station (VRS) network that could be used to correct and refine the GPS position of the vehicle's onboard POS. The GPS base stations were set over pre-coordinated points, and logged GPS data at a rate of one posting per second. The rest of the survey area, whose main focus was asset management, was covered by the obtained CORS data. The CORS, which was added to the established base station network, allowed for the construction of a VRS network that covered the entire study area. The baseline between the Lynx Mobile Mapper and the base stations did not exceeded 18 miles during the survey.

To obtain the highest level of accuracy with the Lynx Mobile Mapper, coordinated targets were placed throughout the design engineering area. Control points were established using multiple RTK GPS locations utilizing different onsite base station locations and the local VRS network.

Survey Execution

Set-up of the four GPS base stations was accomplished 30 minutes before collection began. The local VRS network was checked to ensure that it was working and collecting at a rate of one posting per second on the day of the survey. Targets were set up on the previously identified control points.

Data for calibrating the boresight angles and lever arm measurements was acquired immediately before the study area was surveyed. Once this was accomplished, the vehicle proceeded to a road/rail crossing and the hyrail gear was engaged. Safety checks were performed on the vehicle to ensure that it would activate all signal crossings.

The survey was conducted over a period 10 hours. The route was driven both south to north and north to south. The vehicle driving speed through the populated urban areas of Austin was between 15 and 20 miles per hour; collection speed through the outlying rural areas was 25 to 30 miles per hour. During the survey the POS system was monitored to identify periods of GPS outage. Generally, GPS outages were caused by areas of heavy vegetation and urban canyons. These areas were logged in field notes and on route maps during the survey. Three stops were required during the collection to allow the Lynx data storage device to be changed. During the survey, nearly 1 terabyte of data was collected.

Processing the Data

Once the data collection was complete, all data was sent for post-processing. Data post-processing proceeded in several steps:

1. Raw GPS and POS data was processed using POSPac (www.applanix.com)
2. Lidar data was processed using DASHMap (www.optech.ca)
3. The output of POS-corrected lidar data was then integrated into GeoCue’s Mobile Cue Pac (www.geocue.com). This, in turn, utilized the program, TerraMatch (www.terrasolid.fi) to fit the lidar data point cloud to the control targets.

Two separate adjustments were made for the lidar data. The first adjustment aligned all the collected data to the control. The second adjustment concentrated on the areas where engineering design work would be performed.

To establish the margin of error for the results produced by TerraMatch, cross-profiles of the track were surveyed to establish ground truth. These cross-profiles were surveyed at a few locations along the rail corridor. It was found that the cross-profiles conformed to the adjusted lidar data with horizontal and vertical residuals ranging between 0.04 feet and 0.06 feet. Extraction of relevant features from the point cloud proceeded.

Asset Management

Asset management through GIS database creation or updating can be quite involved. Creation of a planimetric map is a time consuming process that requires skilled professionals. Traditionally, this type of information was obtained through lengthy field surveys followed by CAD operations. The Lynx has reduced the time that field surveys take from days to hours. Therefore, most of the time spent in this project for map generation was in CAD operations. Microstation (www.bentley.com) was used as the CAD engine in this study, with TerraSolid (www.terrasolid.fi) operating on top of the CAD engine.

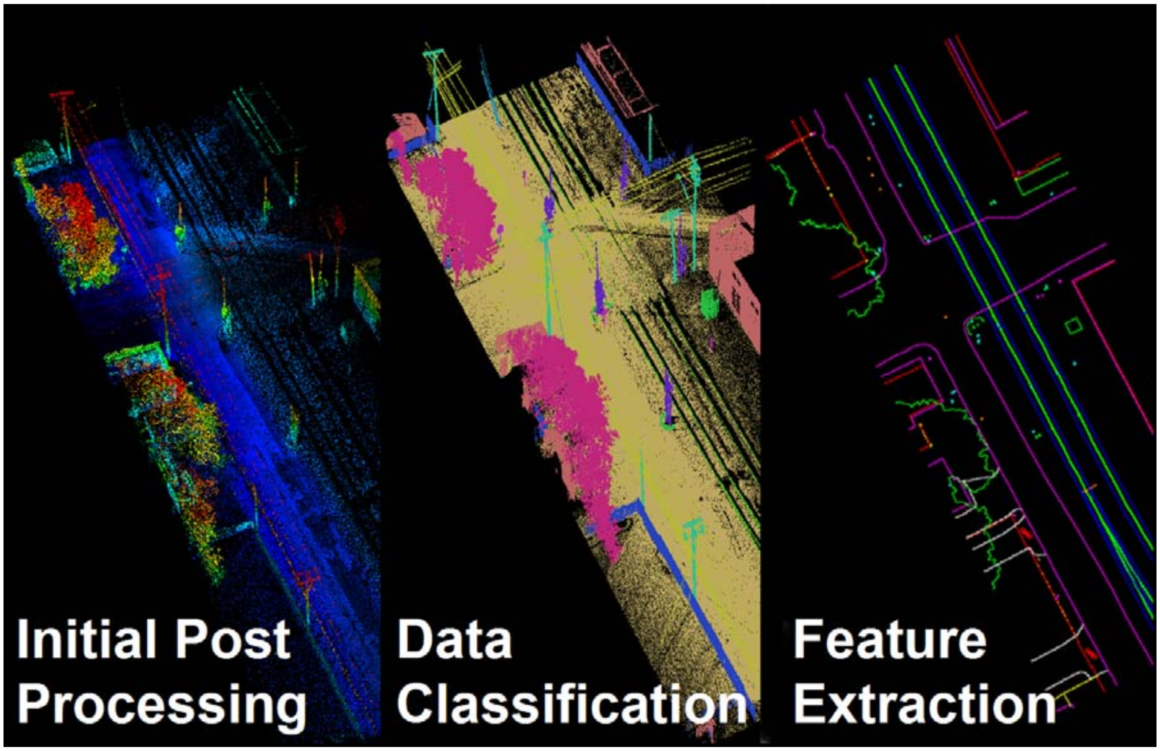

Figure 3. Phases of processing to extract asset management data from a Lynx data point cloud.

Figure 3 shows the progression of data extraction and vectorization from the adjusted point cloud to the final deliverable. After the lidar data had been adjusted to the control data, classification of the collected data began. The multiple returns of the Lynx Mobile Mapper allowed for some classification to be done automatically. The remaining layers were classified through manual selection. Vector data was extracted from the point cloud based on the classified data points through TerraSolid's semi-automatic tracking features and manual digitization. Classification and vectorization of the design engineering area took a total of 100 hours.

Engineering Design

Survey work for engineering design can involve various collection methods for numerous purposes. Establishing accuracy of the survey over the design area is essential to the design process. Having established an estimate of the overall positional error in the Lynx data collected throughout the design area, measurements may be produced from the point cloud with confidence. This part of the study focused on two areas of design work. The first involved the calculation of clearance envelopes in both the vertical and horizontal directions. The second involved as-built mapping of existing bridges along the rail line.

Clearance envelopes are important considerations when designing any transportation system. The minimum, standard, and maximum vehicle sizes that can use the transportation system have to be accommodated in the design. When existing infrastructure requires upgrading, the current as-built design has to be evaluated so that a plan for upgrade can be made. To this end, dimensionally accurate three-dimensional data is invaluable in planning a transportation system upgrade. Figure 4 shows the rail car size that would be expected to fit on this track with relation to overhead obstruction. Clearly, there is room for a vertical height increase along this section of track. All such sections of track along the entire route had to be evaluated, and the maximum size of the rail car will be based on the area of smallest clearance.

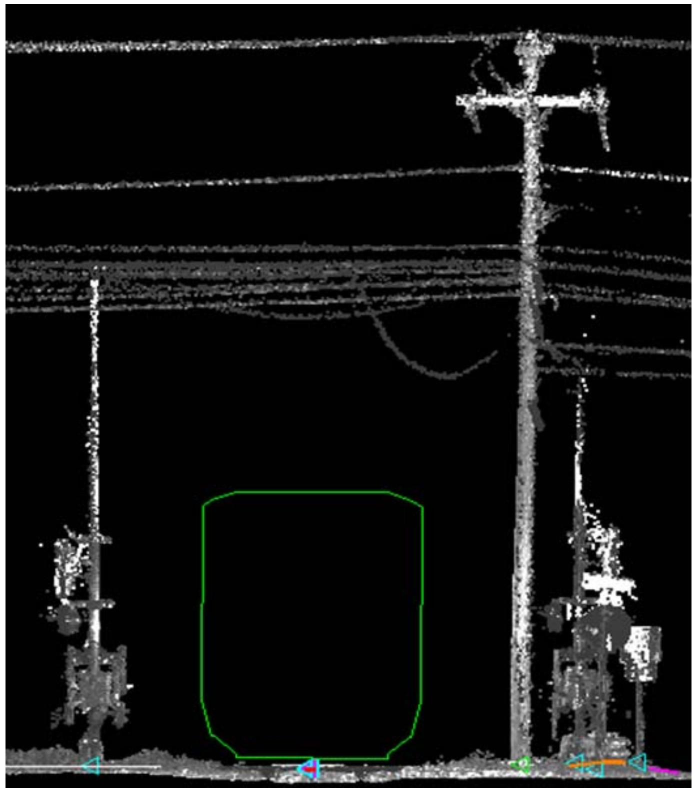

Figure 4. Cross-section of a Lynx data point cloud showing the vertical clearance envelope of the rail line as it passes under a power line.

Height is not the only type of clearance that needs to be evaluated. Horizontal clearance of rail cars needs to be assessed based on protrusions onto the track area. Figure 5 shows the clearance of the same rail car with respect to a platform. The platform intrudes on the clearance envelope, indicating a potential problem with this design. Either the platform will need to be redesigned, or the size of the vehicles using this track will have to be reduced.

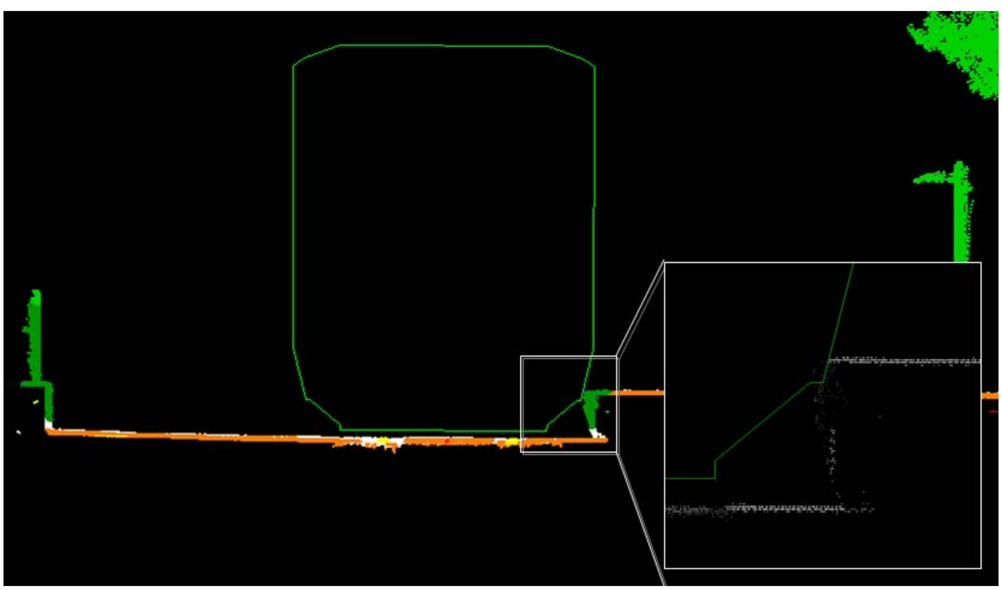

Figure 5. Cross-section of a Lynx data point cloud showing the horizontal clearance envelope of the rail line next to a platform.

Existing as-built designs of bridge and tunnel structures along the track area also had to be evaluated. Figure 6 shows the layout of the existing track and bridge structure. This information is critical in determining whether a) a second track can be laid underneath the existing bridge structure simply, safely and for little cost; or b) if a new track section would involve the redesign of the bridge itself.

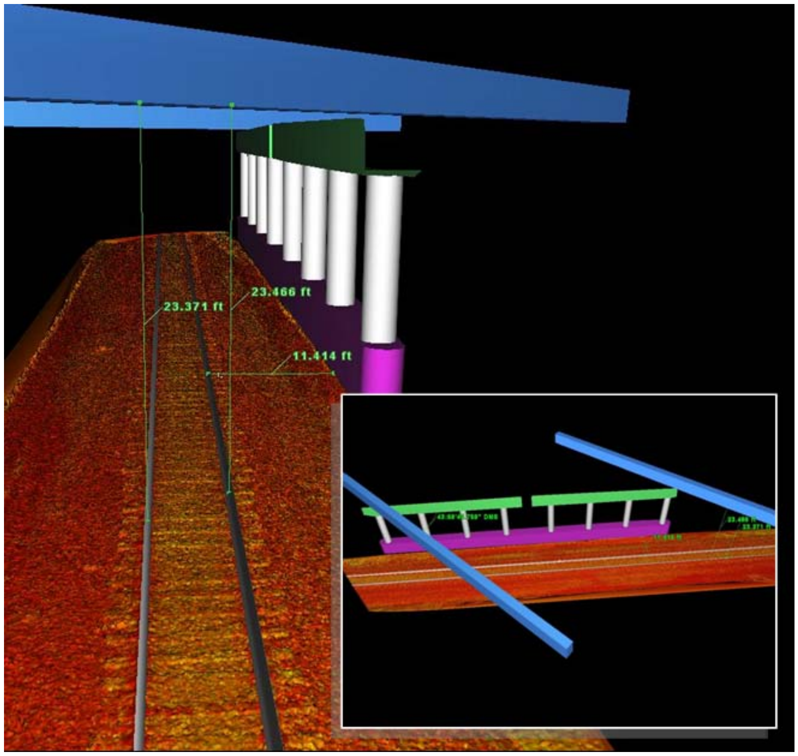

Figure 6. Lynx data and shape primitives of the underside of a bridge crossing the rail line.

Similar considerations need to be made for tunnel sections. Figure 7 shows the design cross-sections of two types of railway tunnels. These cross-sections represent the design plan for a section of railway tunnel, but do not necessarily indicate how the actual tunnel currently looks. As-built data needs to be collected along this route before re-design planning can begin.

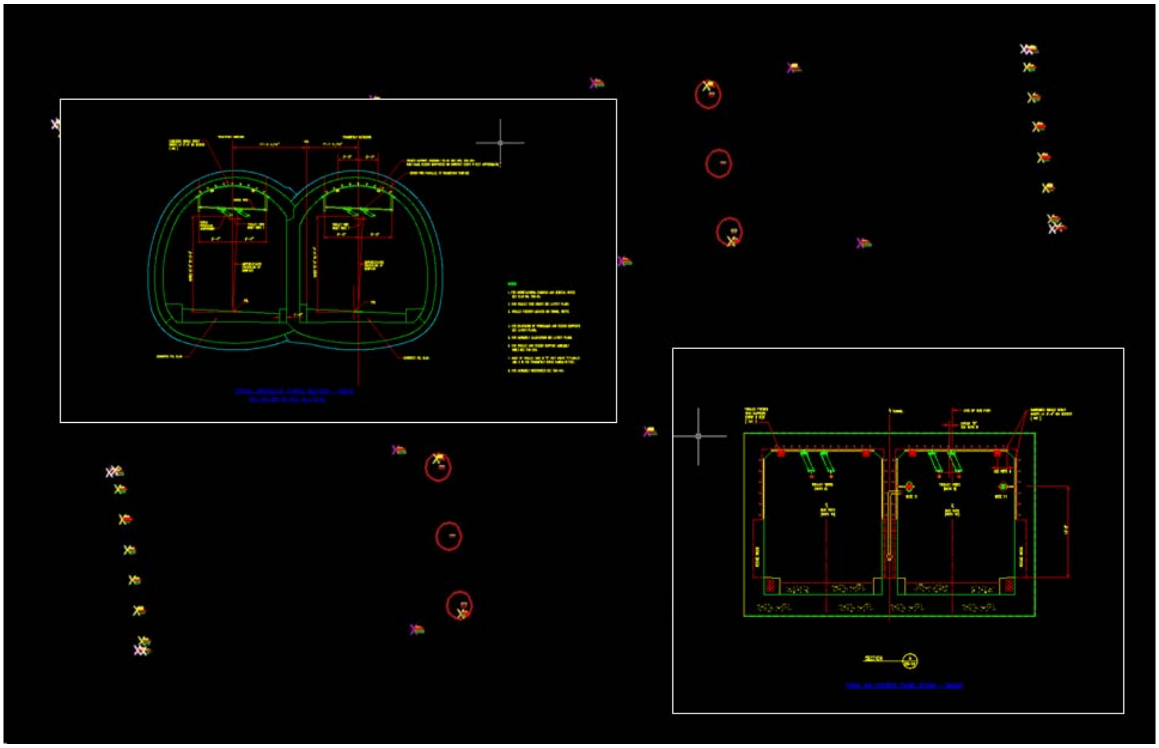

Figure 7. Design cross-sections for two types of railway tunnels.

CONCLUSION

The lidar data point clouds produced from the Lynx Mobile Mapper are feature-rich and contain high-quality data that can be used for a variety of purposes. The data collected in this study was capable of being adjusted to meet accuracy specifications for the project, and produced timely, reliable as-built maps of the design corridor. The rest of the data collected along the survey route was useful in extracting asset data, which was subsequently incorporated into a GIS database of railway assets. The combination of lidar and camera imagery produced a very useful mix of data that proved essential to the success of the mission.

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