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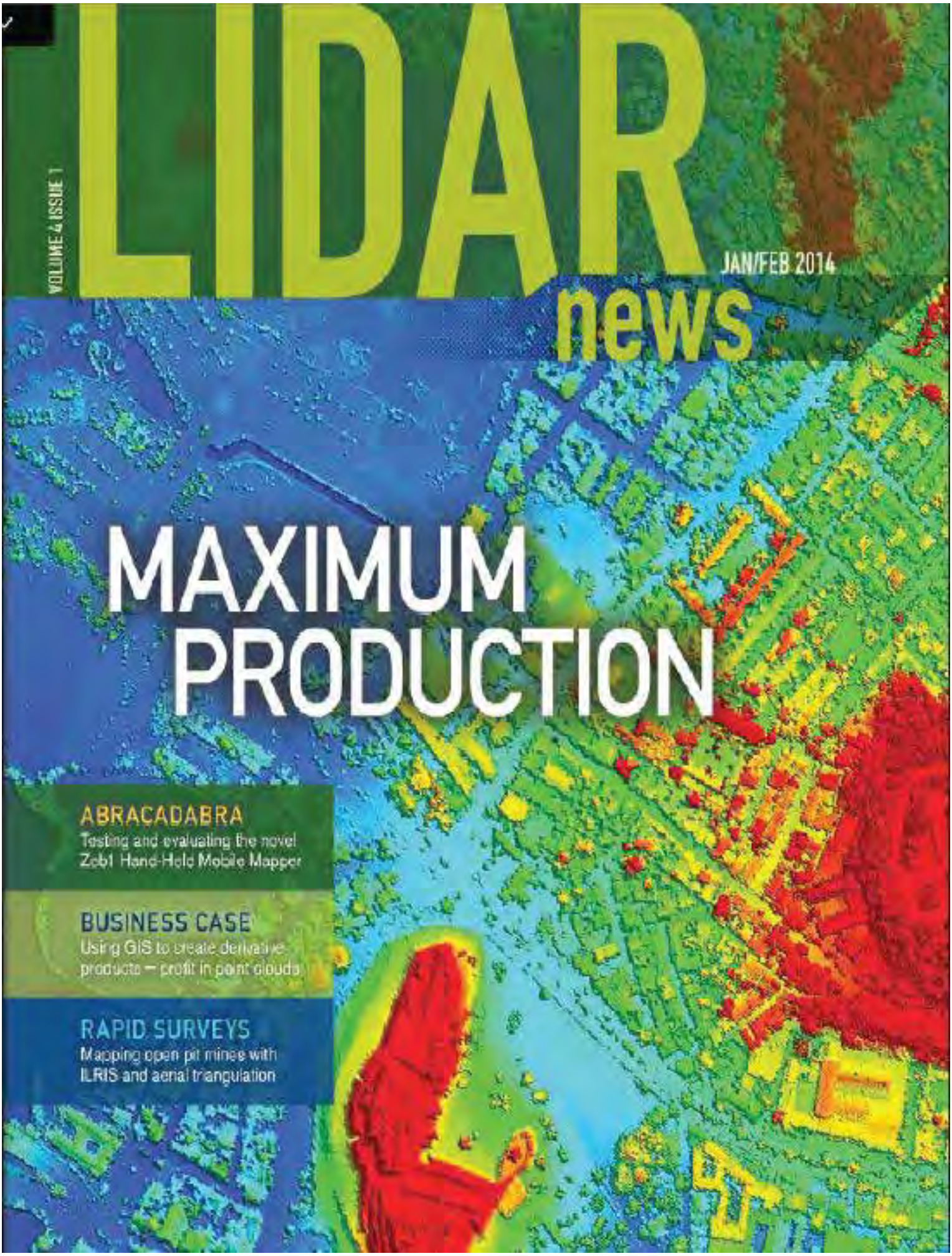

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North entrance to Stuart Tunnel circa 1914.

Century Old Rail Tunnel's Life Extended Through the Use of New Technology

The Stuart Tunnel in the pastoral town of Paw Paw, West Virginia, is not unlike any other freight train tunnel in easter United States that is beginning to show its age. The tunnel, part of an active rail system that links Mid-Atlantic ports with Midwestern markets, was built in 1914 using a drill and blast method with brick and mortar filling. Today, years of weather, usage and maintenance have taken a collective toll on the tunnel, challenging even the most experienced contractors to make repairs. The size of freight is getting bigger, and the speeds of the trains are getting faster, however the infrastructure hasn't change much since the turn of the last century. While the tunnel has outlived its efficiency, as it is, certain modifications being made to this tunnel are making it viable in meeting today's imporved rail transportation market.

The modifications being made to the Stuart Tunnel are part of a massive initiation set forth by CSX Rail, as part

BY RYAN**LEONARD**

Amberg GRP5000 rail trolley being used at Stuart Tunnel project site.

of the National Gateway Project for the Stuart Tunnel notching that has been intiated to meet and expand the growing needs of a competitive freight business. The National Gateway project will imporve the flow of rail traffic throughout the nation by increasing the use of doublestack trains, creating a more efficient rail route connecting its ports.

CSX contracted various skill sets to excavate a linear notch in the upper rims of the tunnel walls to accomodate the larger train car bodies and their swing through the curves. Although tunnel construction has not changed much over the years, grinding out notches in an existing 100 year old tunnel layered with concrete, brick, and mortar is not without obstacles and accuracy is imperative. If predicting where the new cars will encroach the old tunnel walls wasn't enough, years of track maintenance and a century of tamping the track and ballast required an accurate understanding of the existing track alignment, tunnel surroundings and possibly a new design adjustment.

Maser Consulting, PA, a multi-disciplined engineering firm with offices located regionally along the East Coast, was introduced to this particular challenge at the Stuart Tunnel Notching Project through Drill Tech Drilling, Antioch, California. The heavy lifting had already been completed by Drill Tech's expert teams through heavy excavating equipment and grout work. The tunnel's rims had already been notched to near perfection but as with all tunnel work, the devil is in the details - the work had to be executed in the darkness of the corridor and 20+ feet overhead.

Maser Consulting's Rail and Tunnel division approached the project from a comprehensive point of view using traditional as well as several levels of high definition scanning (HDS) technology. Leveraging their previous experience and success on the New York MTA's Number 7 rail extension project, and Dulles extension, Washington D.C. MTA, Maser Consulting's solution was to deploy a rail trolley mounted with a Z&F 5006i phase based scanner to determine any potential encroachment with respect to a proposed new alignment of the tracks.

The Trolley, an Amberg GRP5000, as its core is a geometric measuring sensor, capturing gauge (±0.3mm), super-elevation (±0.5mm), and the x,y,z rail head positioning (± 2mm) along with associated stationing from establishing markers calculated by the onboard odometer. Positional information is established by a robotic total station located by

resection to the local control monuments is continuously tracking a mounted prism on the Trolley. With the inclusion of the phase based 3D laser scanner (GRP5000), the Trolley captures continuous LiDAR perpendicularly about the tracks reaching as far as 79 meters. The complete data set is then geographically referenced to the local control using the Amberg rail software suite.

While there are many technologies and services used to acquire critical data associated with railways and their ROW's, most are cumbersome and require extraordinary logistical challenges impeding revenue services and increasing risk to track workers. Maser Consulting's railroad geometry and ROW data acquisition services utilize the industry's most sophisticated and safety conscience technology. Designed for direct contact with the tracks and highest precision methodology, the Trolley provides comprehensive track geometry and corridor mapping, including gauge, super-elevation, curvature, middle ordinate, clearance and asset inventory. With its simple design upon a flagger's signal, the trolley operators can lift and remove the entire system from the tracks which was critical since this work was performed in a 6-hour uninterrupted daily window, five days a week on one track at a time with trains passing an adjacent track. In revenue track situations, Maser Consulting's safety conscience methods and the use of Amberg GRP reduced the duration of track outages and the needs for lengthy mobilization times.

Maser Consulting's Trolley system provides our operators with the ability to access and exit anywhere along the ROW where access is granted, to begin acquiring data further providing a reduction in mobilization. Using a three-man crew and utilizing a robotic total station for position, Maser Consulting's crews captured comprehensive track geometry and LiDAR information at over ±700ft. per hour, once convenient and accurate controls have already been established. Within tunnel environments, data is gathered at an average traveling speed of 0.75mph, at 250-350 ft. stations. Approxiamately 6,000 LF of track and tunnel data can be obtained during a typical 8 hour work shift.

Since the existing tracks were not in their final position, the tunnel corridor was scanned and the new car body was processed through the tunnel using the proposed design for the tracks. This method used a robotic total station to track and document the position of the Trolley continuously through the tunnel. The data acquired by the team enabled the creation of a complete 3D model of the tunnel, from entrance to exit.

Using a sophisticated clearance algorithms, Maser Consulting was able to super impose the car body on the virtual, new alignment provided by the contractor. Taking into consideration the design super elevation and measured curvature, Maser Consulting's data specialists were able to rotate and expand the car body to accommodate its rotation, center-excess, and end-excess throughout the entire length of the tunnel corridor. Using the laser scanner on the trolley gave Maser Conuslting a complete picture, capturing ever 1/4 inch of the tunnel from rail to tunnel ceiling, identifying subtle deviations in the tunnel notching and grouting.

As per the contractor's request, Maser Consulting implemented a 5 foot cross section profile extraction accommodating a 2.5 foot bandwidth. This technique allows the data speciallists to create a contour of the closest point of promixity, including 2.5 feet before and after the 5 foot cross section, ensuring that none of the features were missed in the computation of the clearance analysis. This technique is most valuable in situations were visible detection and measurements are difficult or when protuding features are exceptionally small yet critical to clearance, e.g. rock bolts, rebar, or wooden plugs.

As part of Maser Consulting's deliverable process, a tiff image representing the scanned image of the tunnel surface was used. Each pixel in the image represented an x,y, and z coordinate. With that, a colorization could be attributed to each pixel value and subsequently a distance from the proposed car body. This enabled them to produce a comprehensive color map of the tunnel surface, highlighting in clear color distinction, each pixel or group of pixels (tunnel features) which represented a potential encroachment. This tunnel map made for quick review to find areas of concern. Then by station location and vertical, perimeter, the contractor easily referred to the cross section profile at that location for a detailed dimension, making arrangements for action that much more deliberate.

Using existing survey control on the project and setting for a few new, convenient points, the team finished the field work in 12 hours. The delivery of the final product of 5 foot profiles and a near photographic

quality tiff image of the entire length of the tunnel was completed within one week of field work. This was five weeks earlier than it is estimated could have been done conventionally with traditional survey equipment and infinitely more detailed than could have been captured by the subjective point of view of field teams.

By using the phased base scanner and the Amberg trolley, literally billions of points created a three dimensional model of the entire surface of the tunnel walls, entrance to exit, top to bottom, while in the dark. Furthermore, each profile generated has its own corresponding stationing set by the designer which is then tagged to each extracted profile. From the profile any encroachments or other points of interest were clearly mapped and identifiable on the deliverable and then in the field verified. By using the x and y coordinate system, Drill Tech's field team was able to navigate back to any area in question and find the feature using an "up and over" dimension clearly labeled on the deliverable. The Team could then find the object and chisel or cut the obstruction as opposed to mobilizing the larger equipment and drilling over a large area.

"Once we saw the deliverables, we knew everything had been captured and we could go back with a scalpel rather than a hatchet to make any changes," stated Michael Wilson, Survey Manager, Drill Tech.

In efforts to maintain the highest level of safety and continuous revenue service for CSX, Maser Consulting's Amberg methods enabled the Team the freedom to come and go, safely from the tracks in a matter of seconds to allow the trains to pass. With superb communications from the CSX dispatch center in Jacksonville, Florida and Drill Tech's expert management, the entire process in the field carried through without incident or interruption.

De-Rollment View of scanned tunnel shows clearance overhead and along tunnel floor.

Highly defined scanned image showcasing griding mark and excavation patterns in tunnel lining.

After a complete analysis by the Drill Tech Surveyor, Michael Wilson and Project Manager, Bradley Middleton, the profiles were devliered in PDF format to the Construction Manager, Transystems/Hill, and subsequently the CSX clearance department for approval.

Railroad tunnels are approached in countless, ingenious methods from coast to coast, continent to continent. Often times there is no single right way to accomplish what is needed. No two projects are the same and for that matter, no two railroads are either. In the case of the Stuart Tunnel., many variables came together just right to make this project a success for Maser Consulting and for Drill Tech.

The scalability of Maser Consulting's Amberg GRP 5000 with its Z&F 5006i phase based scanned helped to densely map the entire surface of the tunnel. Properly registering the point cloud into an accurate depiction of existing conditions enabled the superimposition of a theoretical design alignment. Add in expert communications and the safely conscience culture of all the teams and the National Gateway Project is one tunnel closer to completion.

Mr. Leonard is the Department Manager for Tunnel and Rail services for Maser Consulting. He is responsible for advancing the firm's surveying services and technological expertise through nationwide industry exploration and client relations.