

# Reporter 73

The Global Magazine of Leica Geosystems



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*Leica*  
Geosystems



## A Message from the President

From preventing interruptions on metro lines to ensuring fully-operational sewer systems, we are all well aware how infrastructure is central to a safe and productive community. With the global population increasing one major city every five days, organisations that build and manage vital infrastructure face daily challenges.

From across our global customer base, professionals are using a wide variety of solutions in GIS, laser scanning, mobile mapping and even UAVs to keep critical infrastructures in good condition.

Millions of commuters across the globe depend on several modes of transportation daily. Safeguarding them in Copenhagen are Angermeier and SMT surveying firms using our total stations to monitor possible deformations of the new tunnel structure and affected buildings above ground. The California Department of Transportation employed Leica ScanStations to control design deviations of the ongoing improvement made to the Oakland Bay Bridge, which collapsed during the 1989 San Francisco earthquake.

More and more governments are embracing the concept of smart cities. Improving urban development, IngenieurTeam GEO GmbH used the Aibot X6 UAV to model new construction in 3D for Waldshut-Tiengen, Germany. Without blocking the busy M6 motorway in the United Kingdom, the surveying agency Severn Partnership collected road assets with our mobile mapping solution Leica Pegasus:Two.

Every day, our customers are demonstrating how to solve the world's infrastructure challenges. They are shaping this changing world, and I'm honoured we are a part of that. I hope you enjoy reading this edition.

Juergen Dold  
President, Hexagon Geosystems

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**Cover:** © Severn Partnership  
A Leica Pegasus:Two captures road infrastructure and relating assets. Read the story on page 3.



© Severn Partnership

# Revolution in motion

by Natalie Binder

Severn Partnership strives to provide services to its customers using the very latest and innovative solutions. Since acquiring the Leica Pegasus:Two, the firm of Chartered Geomatics (Land) surveyors based in Shrewsbury, England, has utilised this cutting-edge technology in various infrastructure and construction projects for their customers. Keen to pass on the benefits of this new technology, Severn Partnership was delighted to be commissioned to survey a section of the M6 to collect important assets for their risk and maintenance strategy plan. A full detailed survey of a 17-kilometre (10-mile) section of the M6 in the Midlands area included carriageway limits, crash barriers, assets such as road signs and SOS phones, centre lines, central

reservation, bridge structures and lamp posts. The survey was needed to improve the overall layout of the motorway ensuring regular maintenance checks can be maintained eradicating pot holes and maintaining a smooth and safe road surface for drivers.

The challenges of surveying a section of the M6 motorway are vast, and closing this section of the busy motorway was not an option. Restrictions to access were a serious issue as the motorway needed to remain open whilst the data was collected. The vast volume of assets to be surveyed on a motorway in a short period of time was also important to remember. Using traditional total station instruments to carry out this project would have taken twice the time of using a Leica Pegasus:Two, collecting thousands of points of survey data per day. Logistically and





## Severn Partnership

Established more than 30 years ago, Severn Partnership is a firm of Chartered Land Surveyors based in Shrewsbury, England. Working throughout the UK and overseas, Severn Partnership uses the latest robotic survey equipment, 3D laser scanning technology and 3D modelling software. They offer professional services in geomatics, railway survey services, utilities survey to 3D and building information modelling (BIM), and mixed in a wealth of survey expertise and experience.

In 2014, Severn Partnership made a significant investment in the Leica Pegasus:Two, the new mobile mapping solution from Leica Geosystems, becoming the second company worldwide to adopt this new technology. The Leica Pegasus:Two enables Severn Partnership to scan an impressive 1 million points per second with 120 metre (390 foot) range, resulting in survey grade data being captured in a fraction of the conventional survey time. The use of mobile mapping has allowed Severn Partnership to capture calibrated imagery and point cloud data together, making for higher accuracy and faster data collection.

practically speaking, it is dangerous for surveyors to collect data in the middle of a motorway. The overall cost of the project increases with the need for active traffic management throughout the project cycle. A more efficient collection process was needed.

### **The best solution for mapping the M6 motorway**

Severn Partnership used mobile mapping – the process of collecting 3D geospatial information from a moving vehicle – to quickly and accurately provide customers with 2D and 3D CAD plans as well as fully registered point clouds of the entire route section. These point clouds are millions of individual coordinates measured on anything the laser reflects off, such as bridges and roads and can be used to extract even more information, such as GIS datasets. The device is attached to the roof of a moving vehicle and seven cameras then capture a full 360° dome image every 2 metres (6.5 feet). Simultaneously, a LiDAR scanner records cross section data every 2 millime-

tres (0.08 inches). All this is combined into a single cloud creating a 3D model. The result is a direct mapping of features without the need for complex post-processing of observed data, saving time and resources.

### **A world of opportunity**

The Leica Pegasus:Two and the mobile mapping process have revolutionised the world of surveying. There are huge benefits for using mobile mapping systems, especially for infrastructure projects such as the M6 motorway. Access to the motorway is left clear, with no need to close off roads, as the Pegasus:Two acts in the same way as any other public vehicles, only it is collecting 3D geospatial data. Safety is drastically improved using mobile mapping because surveyors no longer need to stand in the road working under time pressure in critical environments to complete projects. All data is now captured from the safety of a vehicle travelling the same speed as the rest of the traffic.



© Severn Partnership

■ With no need to close roadways, the Leica Pegasus:Two safely captures assets and surroundings.

The speed and accuracy of the data collected is also improved. Using traditional static laser scanning methods, two teams would spend several months to survey the highway and other assets along the 17-kilometre (10-mile) section of the M6. Using the Leica Pegasus:Two, Severn Partnership provided the customer with detailed deliverables in just two weeks. Reducing the speed of data collection means a cost saving for customers of 60 percent when compared with the traditional static laser scanning. Also, larger circumferences were covered, giving more accurate, efficient and complete data using combined LiDAR and photogrammetry.

"At Severn Partnership, we understand the need to invest in the latest technology in order to continue to offer the highest level of service to our customers. Pegasus:Two is one of the most accurate mobile mapping unit on the market and does not need survey ground control installed ahead of it," said Mark Combes, managing director at Severn Partnership.

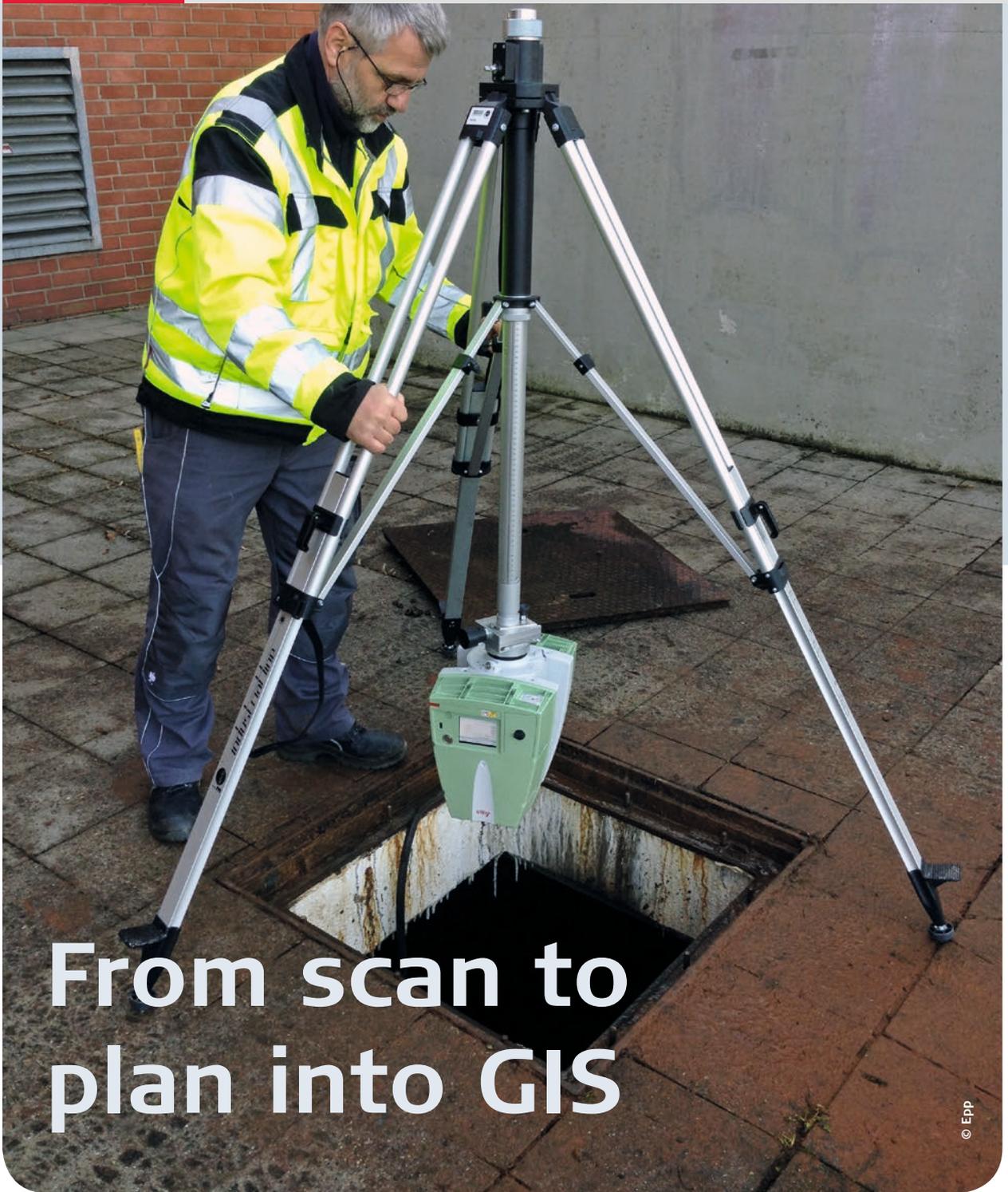
"We will be transferring it between mobile vehicles, cars, vans, roadtrailers, trolleys and other vehicles to scan data across all number of terrain."

The world of surveying is changing and the combining and marriage of multiple technologies has been a giant leap, one which Severn Partnership has openly embraced and serenely adopted for its customers. Mobile mapping has provided a rapid data capture solution, minimising cost, reducing safety risk and maximising value. ■

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# From scan to plan into GIS

© Epp

by Ulrich Epp

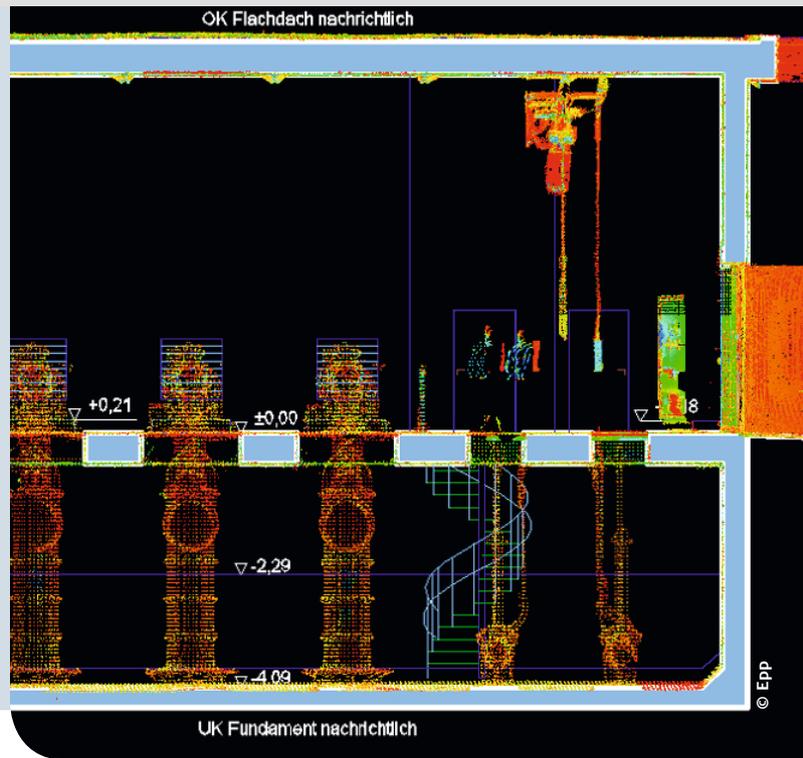
New uses for 3D laser scanners are constantly being uncovered. Many underground structures, especially in sewer construction, are so cramped or inaccessible that total station and manual measuring is practically impossible. Using the Leica ScanStation P20 and a specially-developed shaft tripod adapter, these structures have been economically, accurately and safely

documented in many projects. Leica CloudWorx for AutoCAD not only supplied the client with as-built drawings in all their detail, the scans also enabled the photo-realistic representation of the point cloud and dimensions to be provided over the Internet and to be delivered directly into a geographic information system (GIS).

Many sewer structures are getting old and remedial measures are pending. The construction drawings,

## Creating plans from point clouds

Point clouds deliver an unprecedented level of detail and allow creation of 2D plans or 3D models based on accurate, comprehensive information. This way, intelligent as-built models are created for many applications in civil engineering, plant engineering and pipe construction. When buildings are reconstructed, newly created 3D-designs can be used to detect clashes with point clouds of existing structures. Clash detections can help save time and costs in all phases of a project.



if still available, often deviate from the actual state due to conversions and modifications, and a reliable as-built plan is not available. Measuring sewer shafts is costly and inconvenient due to very close quarters within the structures. Setting foot in these structures is also dangerous: slippery floors, danger of infection and toxic gases cannot be underestimated. A gas detector and full protection gear should always be used when inside such structures. Affordable surveying of these narrow structures can only be carried out by using modern 3D laser scanning technology.

### A high quality scanner and the right accessories

There is one high-quality scanner that can be used for this difficult task. The Leica ScanStation P20 can measure short distances within narrow structures and also offers high data quality on walls prone to moisture.

A shaft tripod manufactured by Nedo is used in combination with a hanging overhead scanner for measuring underground shaft structures. A plate is mounted on the scanner and onto its companion piece on the overhead tripod. This adapter is specially designed to fix the 3D laser scanner overhead.

Prior to using the scanner, a control point network was established using the Leica Viva GS12 GNSS receiver and the satellite positioning service SAPOS. The Leica TCRP1202 total station was then used to densify the network.

After calibration of the points above the sewer shaft, the scanner was then lowered on the shaft tripod into the structure to perform a scan. A classic tripod was used in the larger sewer structures.

It was necessary, however, to loosen several small screws; a task that's not easily carried out in low-light conditions. That's why Nedo teamed up with the Schwelm-based company Goecke to develop the Nedo-Adapter, which can be used in an overhead as well as in an upright position. This combination of hanging and standing scanners thus considerably reduces the time spent in dangerous structures where toxic gases are present.

The processing software Leica Cyclone was used in the office to geo-reference the point clouds. The required plans and sectional drawings were then created using the Leica CloudWorx for AutoCAD.

### Importing the point cloud into the GIS

The point cloud can be edited using Leica Cyclone PUBLISHER in the web browser for photo-realistic representation. The photo-realistic rendering of the point cloud was provided to the client via the Internet in the GIS using the free software Leica TruView for inspection and measurement of the structure.

The municipality of Hennef, a public institution, uses this technique to make the point cloud available in the canal information system noivaKandis, a modern sewer management system based on ESRI



ArcGIS. Employees of the department can easily access wastewater via the web client WEGA-MARS@novaKANDIS by using hyperlinks on the point clouds.

"The user simply selects an object and he or she can access the cloud using Internet Explorer," explains Bernhard Lodewick, head of Data Management and the Survey Department of Wastewater for the city of Hennef.

Using TrueSpace, the desired scanner position can be selected quickly and easily opened in the web brows-

er via the site overview called KeyPlan. A comfortable change between observation points is possible by clicking on the point symbol within the TruView application.

*About the Author:*

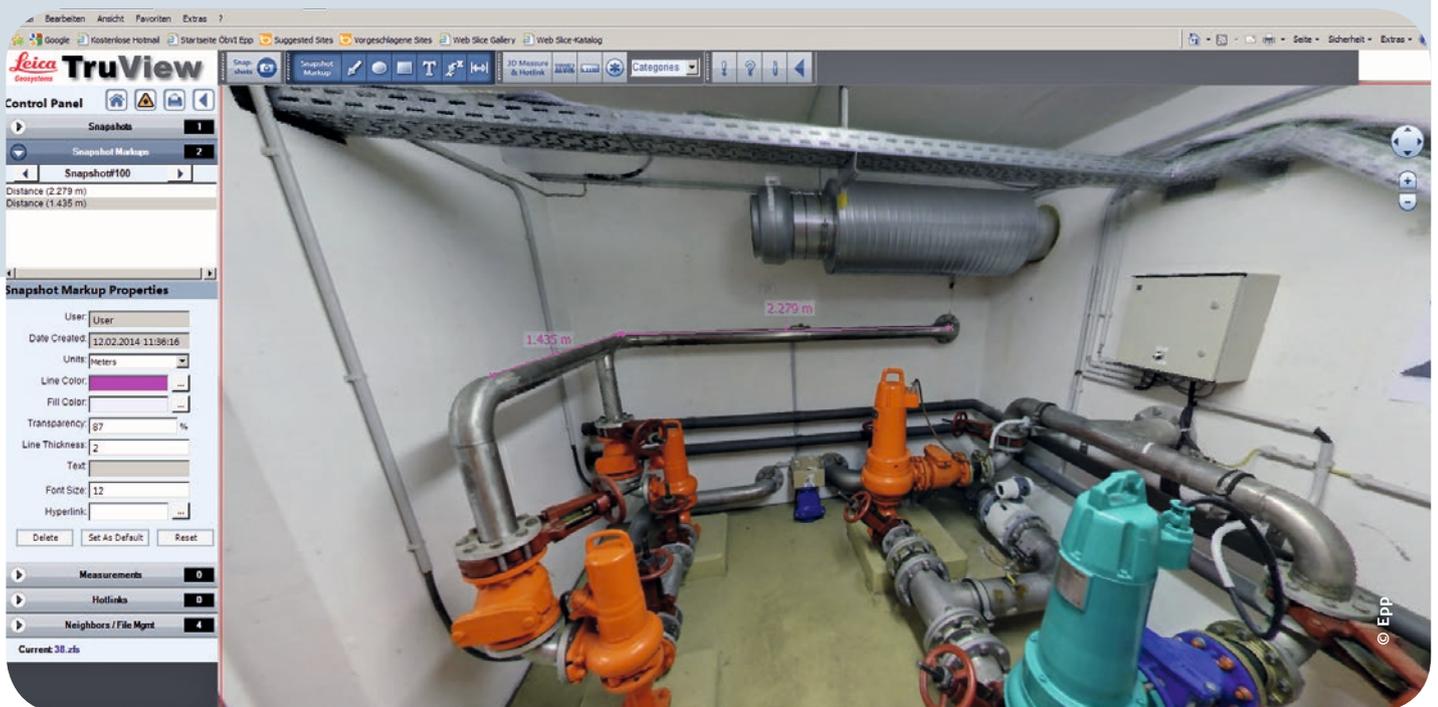
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## Pumping system with dimensions and hyperlinks

Leica TruView produces an optimised point cloud for the web. To enable photo-realistic rendering, multiple photos are taken from the scanner position with a fisheye lens from different positions and with different exposure times using a digital camera. The HDR image (High Dynamic Range image or high-contrast image) generated by bracketing is more realistic than a still image. The photographs are assembled into a panoramic view and then further processed for texturing of the point cloud. The result is a coloured

point cloud, which allows the user to view the data photo-realistically, to tap coordinates and dimensions, and to make sustainable use of the point cloud with no prior knowledge of 3D. Information can also be accessed at any point using predefined hyperlinks. The dimensions and hyperlinks are displayed directly in the graphics. They can then be exchanged for effective communication with users or service providers.





**active** >>  
Customer Care

# So much more than just the red box

With rapid advances in geospatial measuring technology, surveyors are confronted with numerous challenges out in the field - short lead times, quick calls to come on site, time pressure, high accuracy demands, quick reaction to design changes, handling of complex designs, certificates to fulfil quality assurance specs and so on. It is imperative that users receive ongoing training and technical support to deliver maximum productivity and work more efficiently. Lawrence Dixon, after sales director EMEA, details what Leica Geosystems offers in terms of service and support, and explains why the

business is placing a renewed focus on ensuring a positive after-sales experience for all customers provided by a one-stop-shop.

## What does your job involve?

It is my responsibility to oversee all aspects of our after-sales service, whether it is supporting quick and easy communication between site personnel and skilled technical experts, keeping equipment up-to-date and in top condition, or providing first class training. We work in partnership with users to achieve success and there are a range of Active Customer Care service and support packages available,



designed to suit the needs of our diverse customer base. In short, we want the experience of dealing with Leica Geosystems to remain exceptional long after the initial purchase has been made. It is my job to make sure that happens.

#### **Why is there a need for a dedicated role?**

The need for the dedicated after-sales role came about as a by-product of the ongoing success of our geospatial measurement solutions. The technical service capability expanded organically as the business grew, and we always wanted to make sure that we delivered consistently high standards of user experience and product performance, regardless of where a customer was based. We now place service at the heart of our culture, and customer focus is part of the core values of Hexagon.

Users face numerous challenges in their daily lives out in the field, such as time pressure, the need for reliable equipment, data transfer, equipment certification, and the requirement for immediate response and thorough support. It is extremely important that we have contacts and technical specialists that are familiar with the potential difficulties that customers may face.



■ A Leica Geosystems customer receives hands-on training.

#### **Why is the after-sales experience so important?**

If we are to provide the most reliable, innovative and robust measuring solutions, we need to deliver added value beyond the hardware or software itself. The support and service that we offer will help users get up to speed and make sure that their equipment is in top condition, this will help guarantee the maximum level of productivity.

#### **How have the needs of customers changed?**

As consumers, we expect fast response times from businesses, particularly when we need a solution to a problem involving their products or services. This is exactly the same for our customers. They often work in highly pressured circumstances and when they have problems, they need a fix fast. The required speed of this fix has increased year on year and that has been the biggest change.

#### **What does Leica Geosystems offer in terms of after-sales service and support?**

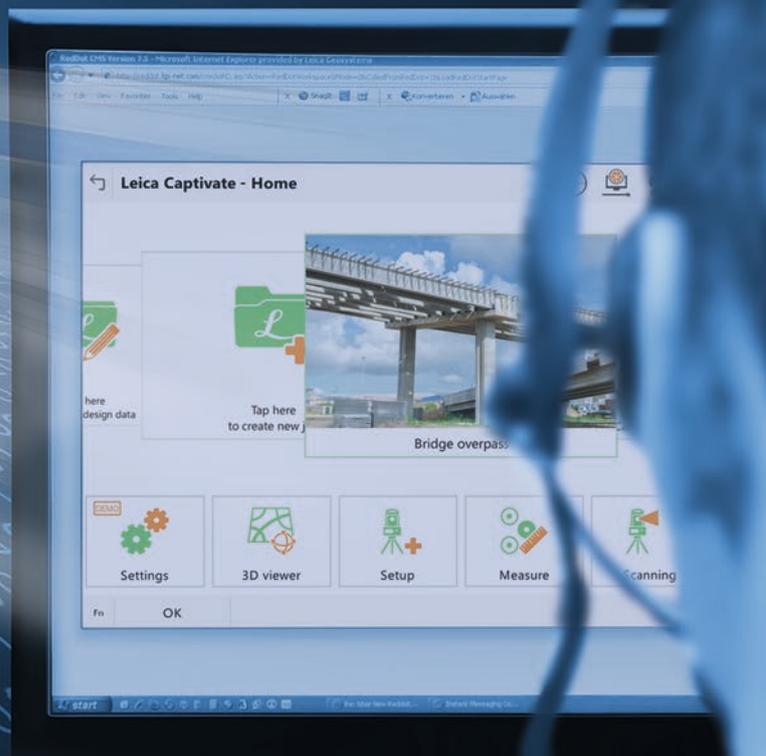
We provide complete after-sales care to users in the field. Our Active Customer Care concept delivers one of the most comprehensive service and support networks in the world, and the ways in which we add value cover three main areas: 'product'-related, like hardware maintenance, repair and calibration; 'people'-related, for example technical support, training and customer communications; and 'workflow'-related, such as the SmartNet Network RTK real-time positioning service. As a result of listening to our customers, we continue to invest in additional personnel and technology, in order to provide the highest level of service, and best access to technical support, in our industry.

#### **How do you know if you are delivering what customers want?**

We listen to our customers. We care about their needs and react quickly to any queries. Running satisfaction surveys offer users the opportunity to provide feedback on their experience with Leica Geosystems and to make suggestions for future improvements. This provides us with both quantitative and qualitative information, which we can use to benchmark our progress and to continually make improvements.

#### **Have technological developments affected the type of support you can offer?**

In recent years, we have seen huge advances in state-of-the-art software services and IT infrastruc-



■ **Leica Active Assist provides direct access to the device for in-the-field support.**

ture, and this allows us to offer enhanced support in the field with maximum security. For example, Leica Active Assist allows a support engineer to remotely access a device directly in the field and give the user a step-by-step guide to the solution. Unique to the industry, Active Assist enables us to focus on harnessing Leica Geosystems' capabilities to overcome the challenges our customers encounter. A further innovation is Leica Exchange, which enables users to transfer data between field and office easily, quickly and safely.

**How does the after-sales experience vary from customer to customer?**

In short, we hope it doesn't! Just as we expect our surveying equipment to perform consistently at a very high level, irrespective of the user, we aspire to delivering the same after-sales experience, no matter who you are or where you experience it. This is of course a challenge for a global business, but is ultimately what stands behind our tagline of "– when it has to be right". Every day we strive to achieve this aim.

One important tool that helps to deliver a consistent experience is the myWorld portal. This online service provides instant access to product manuals and training guides, as well as to an area for the input of support queries. Another useful function for our

customers is the ability to see the status of their equipment when it is in one of our state-of-the-art service centres, allowing them to plan their next jobs around the scheduled return date.

**What do you see as your biggest challenges for the future?**

It is very important that the level of after-sales service and support we provide is consistent across the globe on a country-by-country basis. This is why we continue to invest in additional support and service centre resources, in order to give customers improved access and reduced lead times, and why we encourage our distribution partners to do the same. Happily, we are also a business that continues to grow, so we have to continue to develop and implement initiatives to keep pace with demand. This is a nice problem to have! ■

*For more information on Active Customer Care, visit [www.leica-geosystems.com/acc](http://www.leica-geosystems.com/acc)*

*Lawrence Dixon is the after sales director for EMEA at Leica Geosystems. He joined the business in April 1999, working in various sales roles. He took on his current position in January 2013.*



# Maximum safety for the new Copenhagen Metro Line

by Dieter Heinz

**The Copenhagen Metro Line is among the world's most modern subway systems. To improve the infrastructure in the Danish capital, the city is now expanding its existing metro system by two-thirds through construction of the new "Cityringen" subway loop. Lines M3 and M4 are now being added to the existing M1 and M2 lines. Tunnel-building activities on such a scale in the heart of an old city harbour pose great potential risk due to the unfavourable geological conditions, limited coverage and proximity to existing development. To ensure structural stability throughout the construction phases, various geodetic and geotechnical measuring systems will be used for automatic monitoring in order to detect possible deformations in a timely manner, allowing immediate countermeasures to be initiated. Automated 3D measuring systems, which are installed at every station, shaft and along the stretches of tunnel, play a particularly important role in this.**

The new lines include 17 new metro stations, three shafts with crossovers, and a new maintenance centre. The entire, approximately 15.5-kilometres long, route proceeds through two parallel tunnel tubes in the subsoil of Copenhagen. The new lines will finally connect the central station (København H) and east station (Østerport) to the metro system. Like the existing system, the new metro was also conceived as a driverless, fully automatic system.

The overall costs for the project amount to about 2 billion euros. The Copenhagen Ministry of Transport and the municipality of Frederiksberg are the owners of this major project, represented by Metroselskabet I/S. The executive consortium is an Italian joint venture consisting of Salini/Impregilo Tecnimont and SELI - Copenhagen Metro Team (CMT).

A joint venture of GEODATA Ziviltechnikergesellschaft mbH and ANGERMEIER INGENIEURE GmbH received the contract for monitoring the entire project and founded their own new firm, SMT Denmark ApS, to carry out this enormous assignment.



© SMT Denmark ApS

SMT Denmark ApS is charged with the geodetic and geotechnical monitoring. This includes the precision levelling, conception, set up and servicing of automated 3D monitoring systems, and the installation and servicing of automatic inclinometers, strain and coders extensor metres, and water level gauge measuring systems. In addition, SMT Denmark ApS must also supervise KRONOS, the central project database, where all measurement results, including machine data transmitted every 30 seconds from the four tunnel boring machines (TBM), will be stored. Almost 30 employees are completely dedicated to the monitoring tasks in the Cityringen project.

In January 2012, a start was made to gradually equip all metro stations under construction and shafts with automated 3D measurement systems. Both tunnel tubes are being driven in parallel with the four TBMs. In the process, two offset machines each drive a specific route section in the new subway loop.

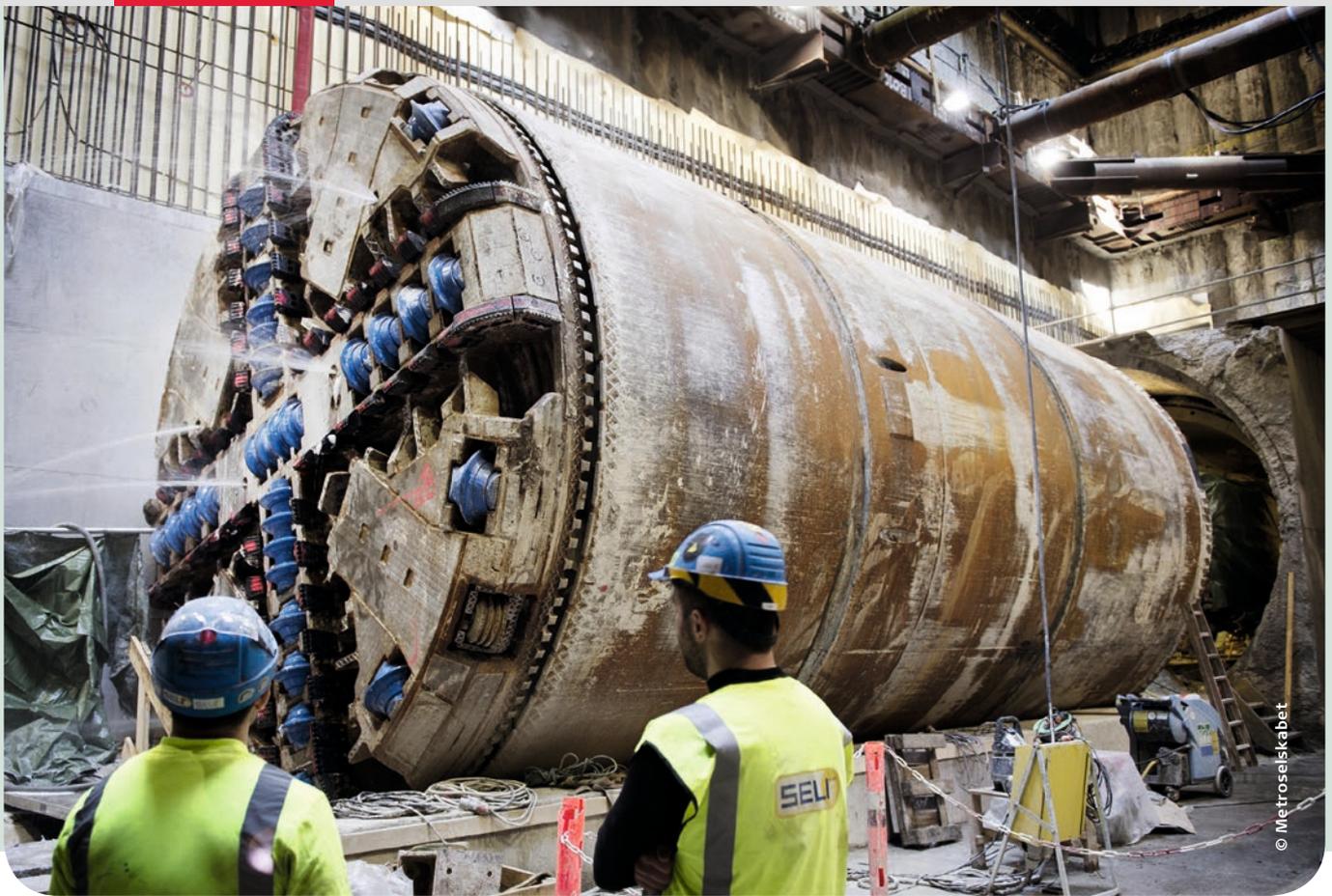
Since summer 2013, the tunnel sections have been equipped with measurement systems during the TBM

drives. In the process, the individual total stations were connected into networks in order to reliably cover the planner's prediction of possible settlements (also called zones of influence). In doing so, up to eight Leica TM30 total stations were connected into monitoring systems that are centrally controlled and monitored by a PC over WLAN.

### **Monitoring instruments from Leica Geosystems**

Both of SMT Denmark ApS's parent companies are long-standing, loyal customers of Leica Geosystems. The choice of supplier for the geodetic measuring instruments and accessories therefore fell on the Swiss premium manufacturer at the very beginning of the project. Over the duration of the project, this proved once again to be an excellent choice, as it was in earlier projects. The measuring instruments operate with such high accuracy that the 3D measuring system and the redundant levelling measurements, which were carried out with the Leica DNA03 level and 2-metre Invar staffs, matched within half a millimetre. The high quality of measure-





© Metrosekskabet

■ A tunnel boring machine arrives at a new station for the Copenhagen Metro Line.

ment results contributed significantly to the project's success.

### 60,000 noiseless measurements per day

The standard measurement frequency is every two hours for all automated measuring systems. In critical situations, the measuring frequency is reduced to one hour or 30 minutes, depending on the particular number of points to be measured.

A special case arose during the monitoring of existing metro tubes when the TBM had to cross the tunnel tubes. Here, the measurement frequency for 10 points actually had to be raised to every 90 seconds in order to be able to give constant feedback regarding settlement during the crossing.

The Software Observer, a proprietary software of ANGERMEIER INGENIEURE GmbH, controlled every total station. It automatically eliminates outliers during every measurement within a measurement cycle. All measurement values are then transferred to an adjustment software and processed. If the results are within the required range of accuracy, the coordinates and protocol are transferred to the KRONOS database, which is proprietary software by GEODATA Ziviltechnikergesellschaft mbH. If there is a data

transmission failure or internal warning or alert levels are exceeded, for example, if the compensator values are outside specified accuracy range, immediate, automatic notifications are distributed to the predefined internal group of people.

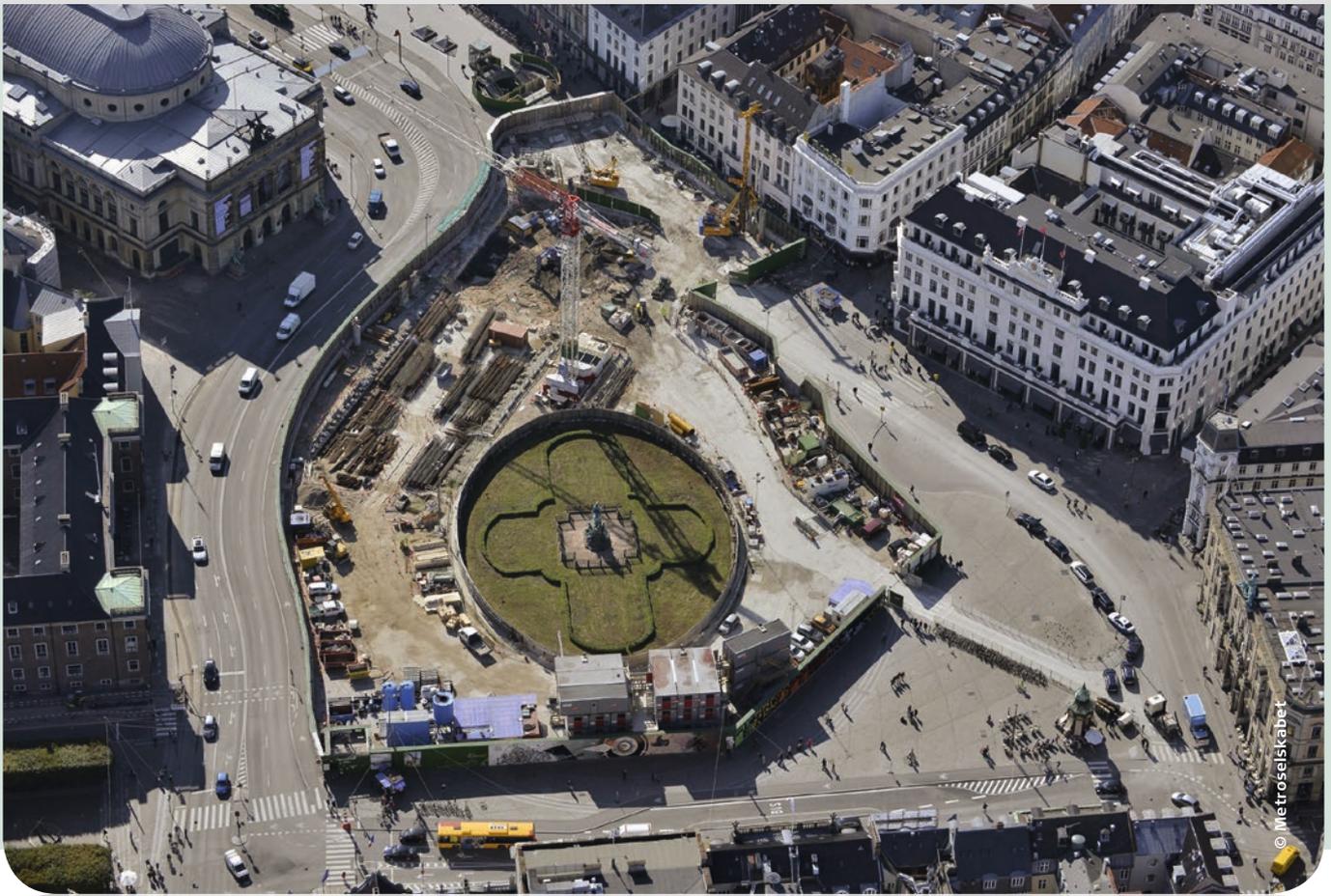
Up to December 2014, 72 Leica TM30 total stations were installed at the 21 new structures. An average of up to 21 total stations run in parallel along the tunnel routes. Approximately four months following completion of a section, they are taken down and reinstalled in the new section.

More than 4,000 prisms were installed with the total stations. Approximately 60,000 measurements per day. Overall, more than 44 million 3D measurements have been carried out so far. Similarly, there were also 600,000 manual levelling measurements.

The extremely low noise generation of Leica Geosystems total stations is certainly worth mentioning. They could easily be installed directly alongside bedroom windows without waking the residents from their sleep.

### Continuous servicing of the total stations

Four employees are responsible for taking care of



■ An aerial view of the construction for the new Copenhagen Metro Line.

the total stations. Their tasks include troubleshooting malfunctions that arise in individual systems and installation of new systems in the station and tunnel sections. After passage of two tunnel boring machines has taken place, they must take down the sensors again. The 3D systems are still in operation at the metro stations under construction.

All computers are remotely accessible from a main centre, which is advantageous when needing to access the network. If an error cannot be corrected through remote maintenance, a local squad sets off to find the problem. Many of these malfunctions are caused by construction activities at the stations, such as interrupted power supplies or restricted visual communication with the reference and deformation prisms due to the large construction machines.

SMT Denmark ApS has added its own lifting platform on a 3.5-ton truck for the installation of prisms and total stations. This is the only way to be flexible and carry out installation and removal or exchange of equipment for maintenance.

### **Experienced teams – reliable systems**

Operating such a large monitoring project for the benefit and safety of Copenhagen's citizens and vis-

itors is a great challenge for the entire team and the measuring system.

As far as the team is concerned, a great deal of experience is required here. Internal processes are continuously optimised. The software components in the Observer are also subject to continuous modifications due to the changing requirements for this complex monitoring project.

The instruments are subjected to a maximum demand for quality, reliability and precision. The demands on the employees, who quickly and confidently respond to every malfunction that arises, are equally high. Monitoring sensors from Leica Geosystems are the perfect partners for this enormous task. ■

#### *About the author:*

*Dieter Heinz is a graduate engineer of the Technical University for Surveying, responsible project manager in the "Cityringen of Copenhagen" project, and a staff member at SMT Denmark ApS.*

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# London Power Tunnels: Checking data integrity in real time

by Konrad Saal

National Grid embarked on a 7-year project, London Power Tunnels, to help ensure future electricity supplies for the UK capital. The transmission infrastructure improvements required a network of tunnels to be built across London, to house what has been described as “a new subterranean electricity superhighway”. Costain Group, one of the UK’s leading engineering solutions providers, was contracted by National Grid to build the tunnels. It used Leica Geosystems’ award-winning Nova MS50 Multi-Station to scan the tunnels and Amberg Technologies’ TMS Tunnelscan software to process the generated information during this project.

In the initial stages of the project, it was clear there would be a number of challenges for the surveying team to overcome. The work involved the construction of 33 kilometres (20.5 miles) of segmentally lined tunnel across central London, including the sinking of 14 shafts and spray concrete lined (SCL) chambers. The excavation of adit chambers around a disused milk depot proved to be one of the most

problematic aspects, as the SCL transitioned rapidly from 4 metre (13 foot) diameter circular to 8 metre (26 foot) high elliptical sections.

Nigel Drayton, senior survey manager at London Power Tunnels was part of the team involved in excavating the milk depot adit chambers. “As the adits changed to the elliptical format, it was very difficult for the human eye to ascertain if there were imperfec-



■ 3D point cloud on the MultiStation display.



tions in the shape of the tunnel. We needed to make sure we had achieved the required tolerances, with the drives cut to 1 centimetre (0.4 inch) of their final profile.”

As is often the case, the new tunnels had to be completed quickly in order to minimise disruption to third party assets. This meant that conventional scanning was not an option. “It simply would have taken too long for the data to be processed,” explains Drayton. The team needed to find an alternative solution, that could provide high precision scanning data in the timeframe required.

As Costain Group engineers had previously worked with Leica Geosystems and had a positive experience, the decision was made to use the MultiStation, which scanned metre-long advances at 1 centimetre (0.4 inch) grid. The data was then run through Amberg Technologies’ TMS Tunnelscan software, which output excavation profiles at 10 centimetre (4 inch) centres in approximately 10 minutes. “We could then quickly check whether any out of tolerance areas needed to be looked at again, before we carried out further work,” adds Drayton.

Once the correct tunnel profile was achieved, it was given a spray concrete lining. The Leica Nova MS50 MultiStation was then used again, while the spray concrete was still workable, to check the newly lined tunnel’s required thickness. The data captured could also be maintained as part of the build records.

### **Accurate tunnel profiles**

By using the MultiStation, accurate tunnel profiles could be produced at a higher speed. Thanks to its seamless workflow and integrated measurement technology, the construction team was able to carry out the necessary scanning and analysis efficiently and accurately. There was a reduction in waste material and the need for reworking, which resulted in time and cost savings for both the Costain Group and National Grid.

Amberg Technologies is a longstanding partner of Leica Geosystems, and the Leica Nova MS50 MultiStation is easily integrated into TMS Tunnelscan. “The crews found the scanner technology easy to use and the technical support on hand was second-to-none,” concludes Drayton. “The structural integrity of the tunnel is absolutely critical and the exceptional lev-



For more than thirty years, Amberg Technologies AG has been developing user-friendly system solutions for geo-referenced data acquisition and processing in the field of infrastructure development. This Swiss company offers standardised products, customer-specific system solutions and project-specific services in the fields of railway surveying, tunnel surveying, tunnel inspections and tunnel seismics.

Three applications collectively known by the name TMS Solution are used for surveying during tunnel

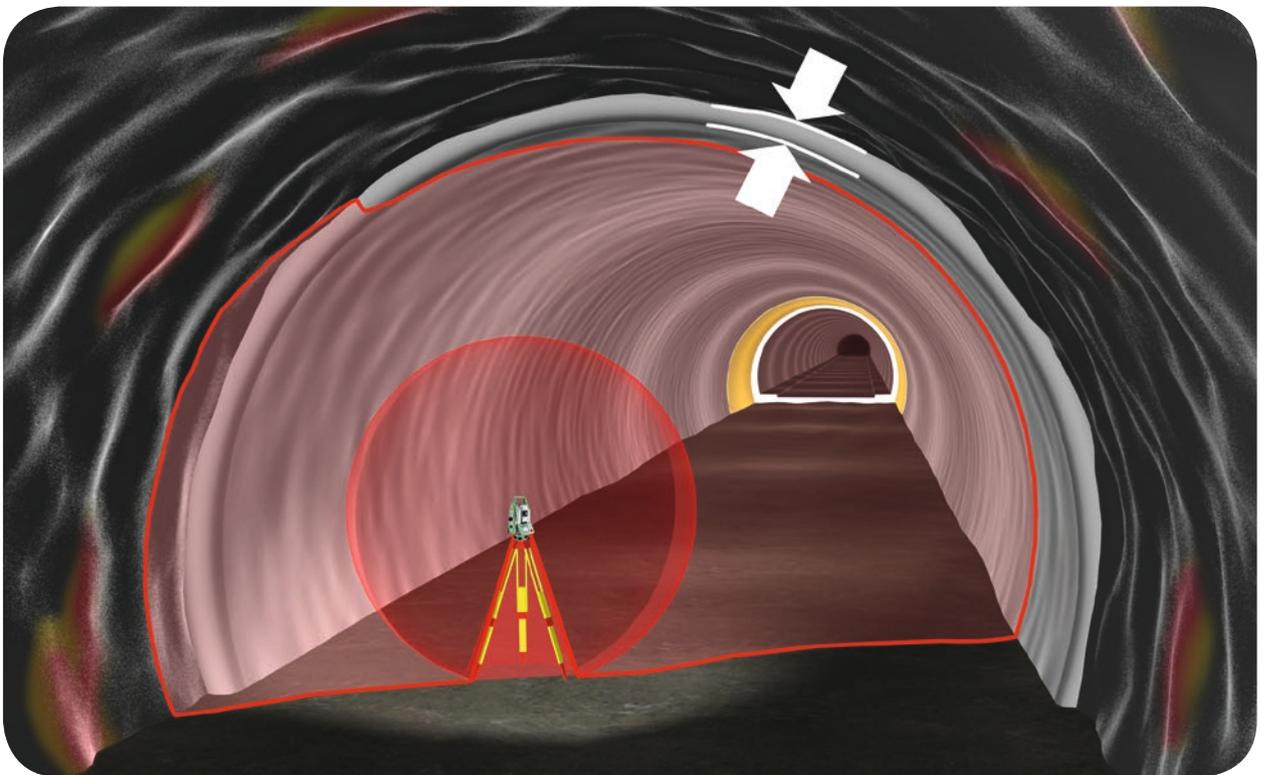
engineering and construction. They allow exact surveying of a wide array of critical aspects such as the tunnel profile, including real time deviations of actual surface to design, automatic control of the tunnel heading and precise setout of all tunnel installations. In addition, complete analysis and documentation of the dimensions, deformations and condition of a tunnel structure form part of the scope of TMS Solution.

el of accuracy provided by Leica Geosystems instruments gave quality assurance we could trust.”

The Leica Nova MS50 MultiStation’s precise measurement technology and intuitive software enables users to make faster, smarter decisions across an unprecedented range of applications. It is the world’s first measuring device that combines scanning, total station, imaging and GNSS positioning in one instrument to deliver fast and reliable results. In 2013,

Costain Group was awarded for the ‘Most Innovative Use of New Survey Technology’ for implementing the MultiStation in the London Power Tunnels project. ■

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■ TMS Tunnelscan and Amberg Navigator support scanning and deliver real-time results.



# Leica Captivate ushers in new industry era

by Monica Miller-Rodgers, APR

When Shawn Crawford started his surveying career more than 24 years ago on a non-robotic theodolite, his dreams of easily categorising jobs and modelling information were far from realised. Phrases like “touch technology” and “customisable apps” weren’t even yet a part of common vernacular. He, like most other surveyors, continued to struggle with how to position large data sets to extract the most value from a project.

Fast forward almost two-and-a-half decades, and we find the advent of the Surveyor 2.0 – the professional who no longer is only expected to measure the angles and distances but also

be the manager of data who has found it part of his daily routine to work in 3D, shaping not only coordinates for a project but modelling the entire design. Thanks to advancements in measurement technology, such as robotic total stations and 3D laser scanning, today’s surveyor is working with better but more data than ever before – data that needs to be carefully sifted through to find meaning.

This process is a detailed one and can take a considerable amount of time and diligence. For years, as measurements have become more complex, surveyors have worked with only a partial representation of the reality of the actual site in software interfaces. Leaving behind critical points, making costly returns to the field once the oversights were realised back



in the office, struggling to find the right project data in an insurmountable set – these are challenges that surveyors know all too well.

### **Introducing a new era in user experience**

Listening to customers like Crawford and analysing the trends seen in smartphones, the developers at Leica Geosystems have released Leica Captivate, the touch-technology software that features customisable apps for a variety of measurement instruments, including total stations, MultiStations and GNSS. The new software allows surveyors and other measurement professionals to bring advanced lining and coding together to provide an interactive 3D model where users can zoom, pan and orbit the rendering for optimal viewing and manipulation.

“When we listened to our customers, the repeating theme was simplicity. Older software wasn’t the easiest to use, and we knew busy professionals needed a better way to access and work with the captures they were collecting in the field,” said Alastair Green, Leica Geosystems field controllers and field surveying software program director. “Our customers often work all day on similar tasks, such as feature coding, linework, and staking points and lines. Keeping these fundamental elements of their jobs easy and enjoyable is very important for a positive customer experience. With Leica Captivate’s easy-to-use apps and touch technology, professionals can now save time, money and hassle by directly updating site information in the most realistic 3D models available in any measurement software.”

In Leica Captivate, users can merge the overlay of measured points, 3D models and point clouds into a single view. This first-time ability allows users to work simultaneously with the current reality of any site, ensuring no points are left out of the image and costly site returns are avoided.

Crawford, the assistant regional director of surveying for ESE Consultants in Boston and a beta tester of Leica Captivate, especially sees the value in being able to check the completeness of a job onsite instead of the need to return to the office to download the imagery.

“Leica Geosystems has taken a giant leap forward introducing 3D scans into the software and now being able to twist and turn that 3D model for even



more viewing opportunities. Being able to view a survey on the screen in the field to look for errors or incompleteness before going from field to office allows the surveyor to make sure he’s collected all the information he needs,” he explained. “The last thing you want to have to do is tell someone he has to go back because he didn’t get enough information.”

### **The world’s first self-learning measurement instruments**

Leica Captivate also boosts the performance capability of the latest generation of Leica Viva and Nova total stations and MultiStations. With enhanced Automatic Target Recognition, or ATRplus, these instruments can now remain locked on one and the same target even in the most challenging conditions.

With optimised sensor technology, ATRplus detects non-relevant distractions in the field, such as reflectors, bright lights and rain, and automatically excludes them from the target. In the case of interrupted line of sight, ATRplus also offers the faster relock time in the industry.

“This is the first step toward artificial intelligence in robotic total stations,” said David Dixon, Leica Geosystems total station program director. “Former



■ **Leica Captivate boosts the performance of the new Leica Viva and Nova total stations and MultiStations.**

lock-on abilities in total stations could become distracted in difficult environments, like rain storms or heat shimmers, wasting time and valuable resources. ATRplus now gives users the confidence they are receiving the right information regardless of the difficulties, freeing them to focus on more critical tasks.”

Along with the new Leica Nova MS60 MultiStation, Nova TS60 and Viva TS16 total stations, the Leica Captivate release also includes a new field controller and tablet. The Leica CS20 and CS35 provide remote access to the MultiStations and total stations and have been updated with larger screens for greater viewing opportunities and easier touch transitions.

### **An all-encompassing solution**

Where surveyors and other measurement professionals have been limited for years by working in 2D virtual representations of their projects, Leica Captivate now opens the possibilities to fully engage with the captured reality of the data. This new software integrated into precision instruments provides for an all-encompassing solution in managing complex practices and information of measuring, checking, staking and scanning. With realistic 3D models and the unsurpassed ability to stay locked on to a target,

experienced professionals and newcomers to the industry can now work with the assurance no point, large or small, is left behind.

For Crawford and other surveyors, advances in technology like Leica Captivate are taking the industry where it needs to be in today’s fast-paced world. As their field continues to progress, their needs and how they express and meet those needs are also changing.

“Leica Captivate is actually making the transition to where our everyday technology is taking us. Like with smartphones, the ability to customise applications with images and interact with those apps through toggling and swiping is very valuable for us,” said Crawford. “We can now view our work right there when we capture it instead of waiting until we get back to the office. Being able to reference yourself inside of a 3D scan, there is just nothing else like this out there.” ■

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# High-end laser scanning under the Elbe River

by Konrad Saal

One of the most important components of northern Europe's infrastructure lies about 28 metres (92 feet) below the surface of the Elbe River: the Elbe Tunnel in Hamburg. As part of the A7 Autobahn, it connects the southern and northern portions of the Hanseatic city of Hamburg and the Scandinavian countries with Europe's metropolises. It is about 3.3 kilometres (1.9 miles) in length, with some 1,000 metres (3,280 feet) passing under the riverbed. At peak periods, up to 145,000 cars and trucks pass through the tunnel's four tubes each day. To ensure the future safety of this important traffic route, the three older tunnel tubes were renovated between 2009 and 2013 in accordance with the updated guidelines for facilities and operations of highway tunnels. The state geoinformation and survey office commissioned the Hamburg based company Dr. Hesse und Partner Ingenieure (dhp:i) with the documentation of every tunnel tube by kinematic 3D laser scanning. The objective was to make current,

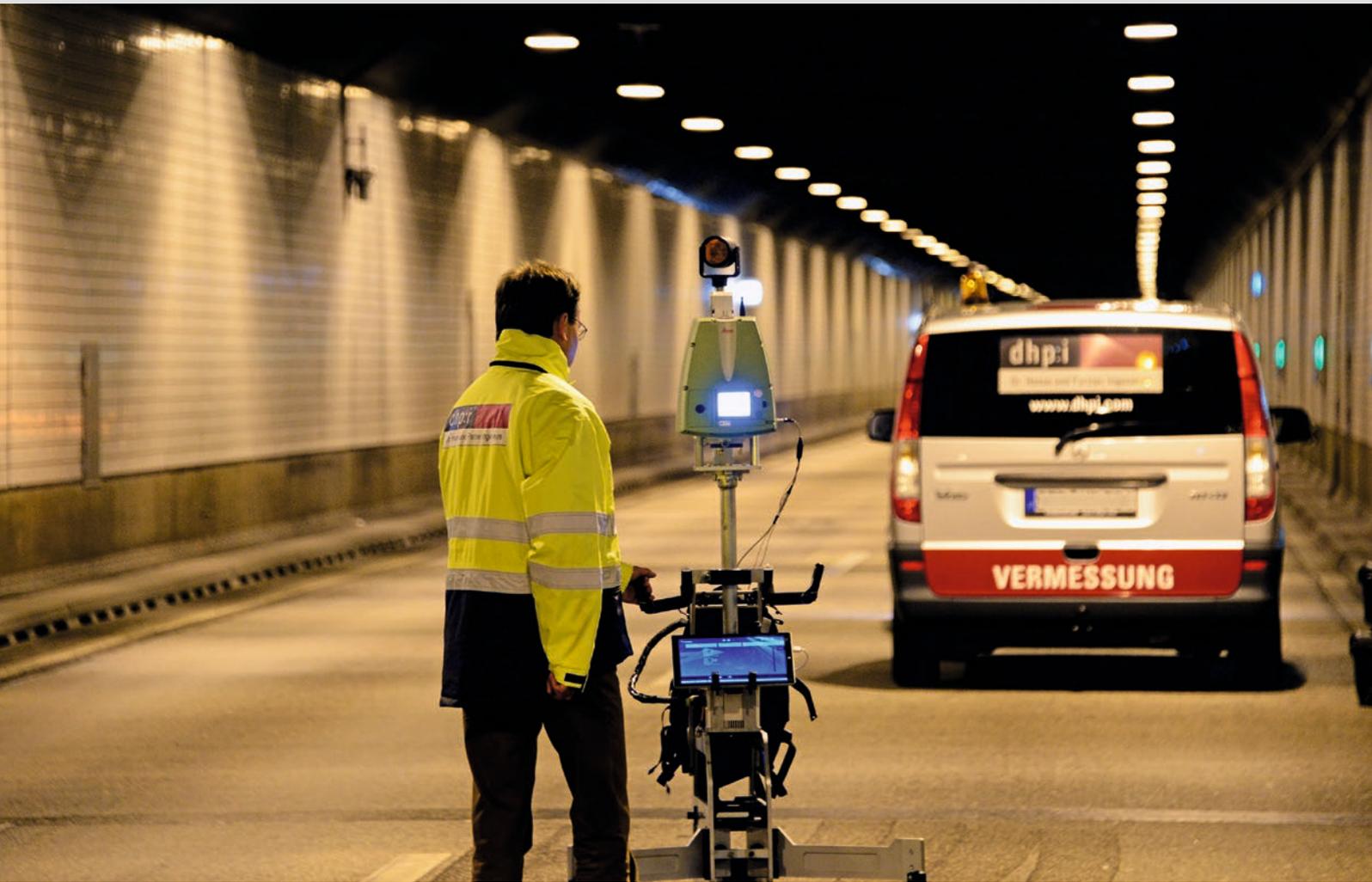
accurate inventory documentation available to the Elbe Tunnel operator (LSBG, state office for roads, bridges and waters).

The georeferenced information obtained will be needed for maintenance and repair support of Elbe Tunnel planning, design, construction and administration processes and as a basis for future Building Information Modelling (BIM), among other uses.

In addition to the tunnel geometry, all other objects and equipment in the tunnel also had to be recorded for this purpose within an accuracy of a few centimetres. This includes supply and safety installations, such as transport equipment, emergency exits, escape route signage, emergency phone and operations alcoves, fire protection systems, ventilation shafts, lighting systems, cameras, loudspeakers, and sensors for traffic telematics and operating technology, totalling more than 200 different 3D objects.

## Selecting the appropriate procedure

Because of the Elbe Tunnel's critical importance for traffic in and around Hamburg, the survey could only



result in minimal blocking periods. It was, therefore, clear from the outset that the activities would have to take place in the low traffic period between 10 p.m. to 5 a.m., and only one tunnel tube could be blocked at a time.

The client's invitation to bid explicitly specified surveying by means of kinematic laser scanning. In the course of the tendering procedure, several vehicle-based and mobile scanning systems from different bidders were evaluated. At the end of the selection process, the decision was made in favour of the ProScan T-Series system from p3d systems GmbH. In addition to other features, easy integration of the Leica ScanStation P15, high acquisition speeds and extremely accurate object recording were persuasive.

"The kinematic scanning system used by dhp:i not only guarantees us maximum precision but also a complete recording of the entire tunnel structure. We have the confidence of being able to rely on the data quality and, at the same time, minimise the blocking periods for this important tunnel," says

Bernhard Cieslik, engineer and manager of municipal surveying at the state geoinformation and survey office responsible for the project.

The kinematic ProScan T-Series system – the T stands for tracking by means of total stations – is a manually guided, mobile laser scanning system. An inertial measuring unit (IMU) and a standard laser scanner, such as the Leica ScanStation P15, are adapted to a trolley. In addition, there is the tablet PC for data acquisition and control. Precise positioning in this project was ensured by Leica TS30 and Leica Viva TS15i total stations, which tracked the prism mounted on the system with around eight measurements per second.

One of the advantages of this acquisition method is direct system referencing through tracking with the total stations. This eliminates the laying out of control points that vehicle-based systems require. Secondly, the high accuracy of the point cloud, combined with very high resolution, and the opportunity to process and check the data shortly after measurement directly "on site" is impressive.



The first forecasts revealed that it would be possible to record one tunnel tube per night in high resolution with this solution.

### **The measurement – one tunnel per night**

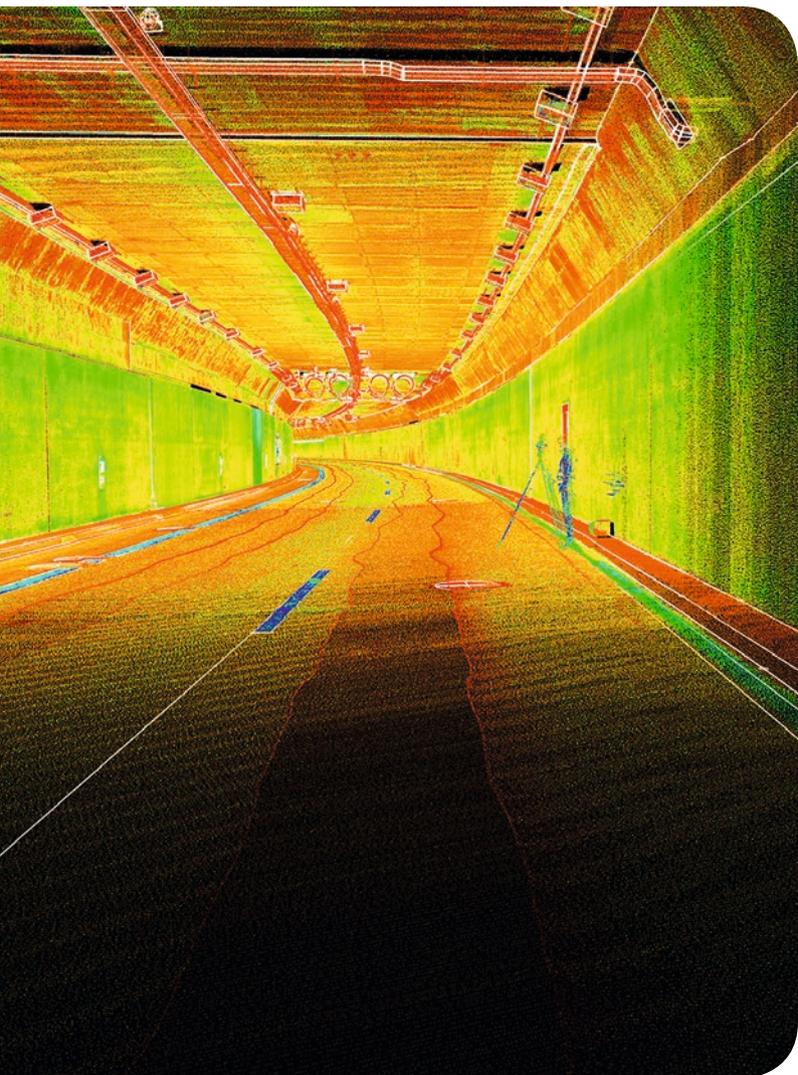
The survey of four tunnel tubes took place in four night-time operations. The intensive preplanning and detailed measuring concept ensured a smooth operation for both data acquisition and evaluation. It was possible to significantly improve on the target duration of nine hours per surveyed tunnel tube from the first measurements.

As part of the on-site scanning, both the tunnel walls and all installations, such as signs and ventilation systems, are recorded completely. For this purpose, the tunnel tubes were divided into approximately 300

metre-long (984 foot) sections that were scanned forward and backward within about 40 minutes.

Thanks to the double recording, all shadowing was eliminated. It was also established that the accuracy achieved in this project was better than 10 millimetres (0.4 inches).

To use the kinematic scan system as efficiently as possible, without interruption, the three on-site project employees' tasks were meticulously coordinated. One employee steadily moved the ProScan along the 300-metre (985-foot) tunnel section, while the other two employees ensured precise system target tracking with their two total stations. Thus, downtime only occurred at the beginning and end of measurement and when changing batteries.



## **Data provision in compliance with specified standards**

Many federal states use standardised data models for infrastructure and other construction projects. Standardisation catalogues regulate the contents described therein, which should supply uniform data to every specialised field that works with this information.

Since 2008, the Hamburg standardisation catalogue has described a detailed standard for digital traffic planning databases. In particular, the catalogue regulates the data structure, data format and signatures. For example, the layer structure, layer names, line types and blocks or hatching and dimensioning are defined in this standard.

As an extension of the two-dimensional Hamburg standardisation catalogue, every CAD object to be modelled and the entire tunnel geometry were constructed in 3D in this project.

The horizontal and vertical fixed control points in the tunnel, which were established by the state's geo-information and survey office and normally used for audit surveys and building projects, could be used for positioning total stations.

The speed with which the measuring engineer moved the system through the tunnel was adjusted to the required object resolution. Due to the number of small objects on the tunnel walls, a measuring point distance of better than 2 centimetres (0.8 inches) had to be guaranteed, which resulted in a scanning speed of 0.5 metres/second (1.6 foot/second).

"Although we have already carried out projects in the double digits with this system, the acquisition speed with the Leica ScanStation P15, the Leica Geosystems total stations and the p3d ProScan is always impressive. A comparable object resolution using tripod mounted and, therefore, static laser scanning would have required at least three times as much time," summarises Dr. Christian Hesse, CEO of dhp:i.

Upon completion of the laser scan, the total station measurement data was imported from the memory card on-site and the automatic geo-referencing of the scan in p3d PCloud began.

The completed point clouds were imported into the Leica Cyclone 9, filtered and cleaned. To carry out the preparation of several thousand 3D objects efficiently, the Cyclone databases were integrated into AutoCAD with the help of Leica CloudWorx Plug-ins. The parallel modelling of required CAD objects and the entire tunnel geometry then took place.

The result was 13.5 kilometres (8.4 miles) of Auto-bahn tunnel recorded precisely at high resolution in four nights, a completely satisfied client, and the happy motorists who hardly noticed anything. ■

*Dr. Hesse und Partner Ingenieure (dhp:i) is an internationally active survey office with headquarters in Hamburg and is among the leading firms in the field of 3D laser scanning.  
info@dhpi.com*



## Elbe Tunnel construction and renovation

After a seven-year construction period, the first three Elbe Tunnel tubes were opened to traffic in 1975. Since the expansion in 2002, four tubes are available with a total of eight lanes. An extensive renovation of the first three tubes took place between 2009 and 2013. Under the name "A7 - Elbe Tunnel retrofit program," asbestos abatement, improvement of the ventilation system, fire protection, escape routes and technical facility modernisations were implemented.

These construction activities were necessary for the tunnel to comply with the "Guidelines for Facilities and Operation of Highway Tunnels" (RABT 2006) that were current at the time.

The Elbe Tunnel is operated by the Hamburg state office for roads, bridges and waters (LSBG).

# 3D vision of an ancient city

by Katherine Lehmuller

The archaeological site, Laodikeia, is one of the largest and most important archaeological sites in Turkey today. Located 6 kilometres (3.7 miles) north of the modern day city Denizli, Laodikeia extended its borders to cover more than 90,000 square metres (968,750 square feet) and has at least 10 important building ruins, including one of the seven major churches of Early Christianity mentioned in the Book of Revelation from the New Testament. Built in a first-degree earthquake zone, the city suffered from multiple devastating earthquakes and was rebuilt many times before its residents finally abandoned it and moved away around 600 AD.

The municipality of Denizli was able to secure financial support and for the last 10 years, extensive excavation and restoration work has been done by Pamukkale University's Department of Archaeology and Ministry of Culture and Tourism under the leadership of Prof. Celal Şimşek authorised by the Council of Ministers. Due to the ancient city's size and because Laodikeia is one of Turkey's most important heritage sites, much time and expense has been dedicated to creating maps and models of the

site in order to document its progress and also to plan for future excavation in the coming season. Recently, the department decided to try working with an unmanned aerial vehicle (UAV) and hired the Aibot X6 from Aibotix. They were extremely happy with the results.

"We could implement the Aibotix flight missions into our yearly workflow. It is quite a fast and beneficial way to see what we have done in one excavation period because the high resolution ortho-photos show progress outstandingly," says Şimşek.



■ Highly detailed image of the sacred temple.



Using the Aibotix UAV to generate data for a 3D city model took the team very little time to accomplish. H. Bora Yavuz, working as a technical consultant for Sistem A.Ş., Leica Geosystems' distributor in Turkey, explains, "With conventional methods, it would take almost 10 days with five skilled people just for the field work alone and if you consider the modelling processing, we would have probably needed another 10 days in the office using trained operators. Now, using the Aibot X6 hexacopter UAV and software, we made a city model within five hours and we needed only one trained person for the entire mission."

After Leica Viva GS15 receivers were used to establish ground control points in the field later used for geo-referencing, a compact 16.2 MP digital camera was strapped to the Aibot X6 copter's camera mount. The Aibotix software, AiproFlight, was used to plan the flight mission of the copter and enabled planning flight details such as keeping the copter at a 70-metre (230-foot) height throughout the entire recording and allowing a model accuracy of 3 centimetres (1.18 inches) ground sample distance (GSD). After this, the actual flight's direction, resolution and route were planned and uploaded onto the Aibot X6. When this was done, data acquisition during the flight was entirely automatic.

Because of the Aibot X6's special panning camera mount, 45 degree image angles were possible with an overlap of 80 percent, and could generate detailed images of side walls, for example.

For processing, the images were geotagged using the ground control points established in the field by special processing software Agisoft Photoscan Pro, which created 3D models and processed high resolution ortho-photos very efficiently and smoothly.

"It has never been simpler to obtain a high quality data set of aerial imagery for documentation, to have an accurate digital topographic model, and most importantly, a high resolution ortho-photo of the area that shows every single stone in its actual position. Besides, this UAV is safe and fast," explains Özhan Kaynarca, company owner Ölçen Harita Surveying Services. ■

*For more information about the ancient city of Laodikeia, please visit: [www.laodikeia.pau.edu.tr](http://www.laodikeia.pau.edu.tr)*

*About the author:*

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# Building cities using UAV



by Martin Schwall and Benjamin Busse

The twin cities of Waldshut-Tiengen, Germany, have approximately 22,000 inhabitants and are located on the beautiful Upper Rhine in Baden-Württemberg near the Swiss border. The local municipal planning and building control office needed an up-to-date planning framework for the newly planned city construction projects and urban development in the two districts. After being reviewed, the documents were simply not accurate enough, even though they had been existed in 3D format. This was due to an insufficient level of detailing, also referred to as LoDs (Level of Detail). A block model (LoD1) and standardised roof shapes (LoD2) were insufficient. The municipal planning and building control office needed a more accurate 3D model as a basis. How could the exact data of complex roof shapes be obtained without the risk of walking on steep roofs or being forced to hire a company to carry out aerial photography by airplane or helicopter?

The IngenieurTeam GEO GmbH has successfully employed an Aibot X6 from Aibotix for several years and was commissioned by the city of Waldshut-Tiengen with UAV flights for aerial surveying and data processing to create geo-referenced ortho-photos, coloured point clouds and 3D models. The project included obtaining the roof geometries as well as eave and ridge heights. The data obtained was then further processed by Autodesk programs – right up to 3D modelling.

## Providing a better basis for decision-makers with 3D modelling

The municipal planning and building control office sought to create an accurate 3D model to visualise the striking new building projects in the centre of Tiengen and in areas of the city Waldshut prior to construction planning. In contrast to plans presented on paper, 3D modelling has the power to truly depict reality and convince the public and the decision makers.

IngenieurTeam GEO's aerial surveying services were already well known. Thus, the idea for using an



ortho-photo to supplement existing LGL (State Agency for Spatial Information) data with current aerial survey data to increase accuracy was the next logical step.

### **Convenient and secure data capturing**

The flights for the aerial survey of the 70,000 square metres (753,500 square feet) of land comprising Waldshut and Tiengen were carried out in May by employee and certified Aibot pilot Benjamin Busse. Aerial surveying of the inner-city requires a special permit and adherence to certain requirements.

The raw data was evaluated with Agisoft Photoscan Pro software. Prior to the aerial survey flights and for the subsequent calculations required to ensure accurate results, control points were measured, marked and signalled using a Leica TPS1200 total station and a Leica Viva GNSS system. Adhering to the principle of surveying “no measurement without control” and to ensure consistent position and height data within the range of  $\pm 5$  centimetres ( $\pm 2$  inches), control measurements were also carried out using the total

station at individual buildings during establishment of the control points.

The Aibot X6 UAV system offered many advantages during this project. The system's quick implementation and high resolution 16.2 megapixel images delivered the accuracy required for the project. An exact recording of the roof types, ridge heights and eave heights would not have been possible with conventional measuring methods due to the close proximity of the buildings in the affected areas. The roof ridges would not be visible due to excessively steep sights.

### **A picture is worth a 1,000 words**

The real benefit, however, lies in the data gathered. This data provides the client with a high level of added value, a textured 3D model, a coloured point cloud and ortho-photos with ground resolution of 1 centimetre (0.4 inch) for optimal representation of the planning area.

Partner company Bytes & Building GmbH, which advises the town of Waldshut in the area of Auto-



## Level of Detail (LoD)

Level of Detail (LoD) refers to the various levels of detail in the presentation of virtual worlds. LoD concepts are also used in 3D landscape and city models. Depending on the application, different levels of detail are required.

The City Geography Markup Language (CityGML) is an application schema for storing and sharing virtual 3D city models. CityGML has been a standard for the Open Geospatial Consortium (OGC) since August 2008 and is the basis for many city models in Germany.

The following levels of detail have been specified for CityGML:

- LOD 0:** Regional model, 2.5-D footprints
- LOD 1:** Block model, building block (extruded footprints)
- LOD 2:** 3D model with standard roof structures and simple textures
- LOD 3:** Detailed (architectural) building models
- LOD 4:** LoD 3 building models with interior features

CAD systems, were responsible for the visualisation. Bytes & Building GmbH provides comprehensive solutions in the fields of architecture, building and infrastructure and occupies a leading position in Germany in the construction industry and building information modelling (BIM). When Bytes & Building submitted the 3D models and a 3D animation of city areas there was nothing but praise and enthusiasm from the head of the Civil Engineering Office, Uwe Kopf.

“We are thrilled! The data and information provided have literally given the planning and control office a whole new perspective,” explained Kopf. “Since the visualisation goes beyond 2D floor plans and 2D building facades, the current high-resolution ortho-photos and 3D modelling have immense value for us. This greatly simplifies the decision making process further down the road.”

### The perfect complement to classic measurement methods

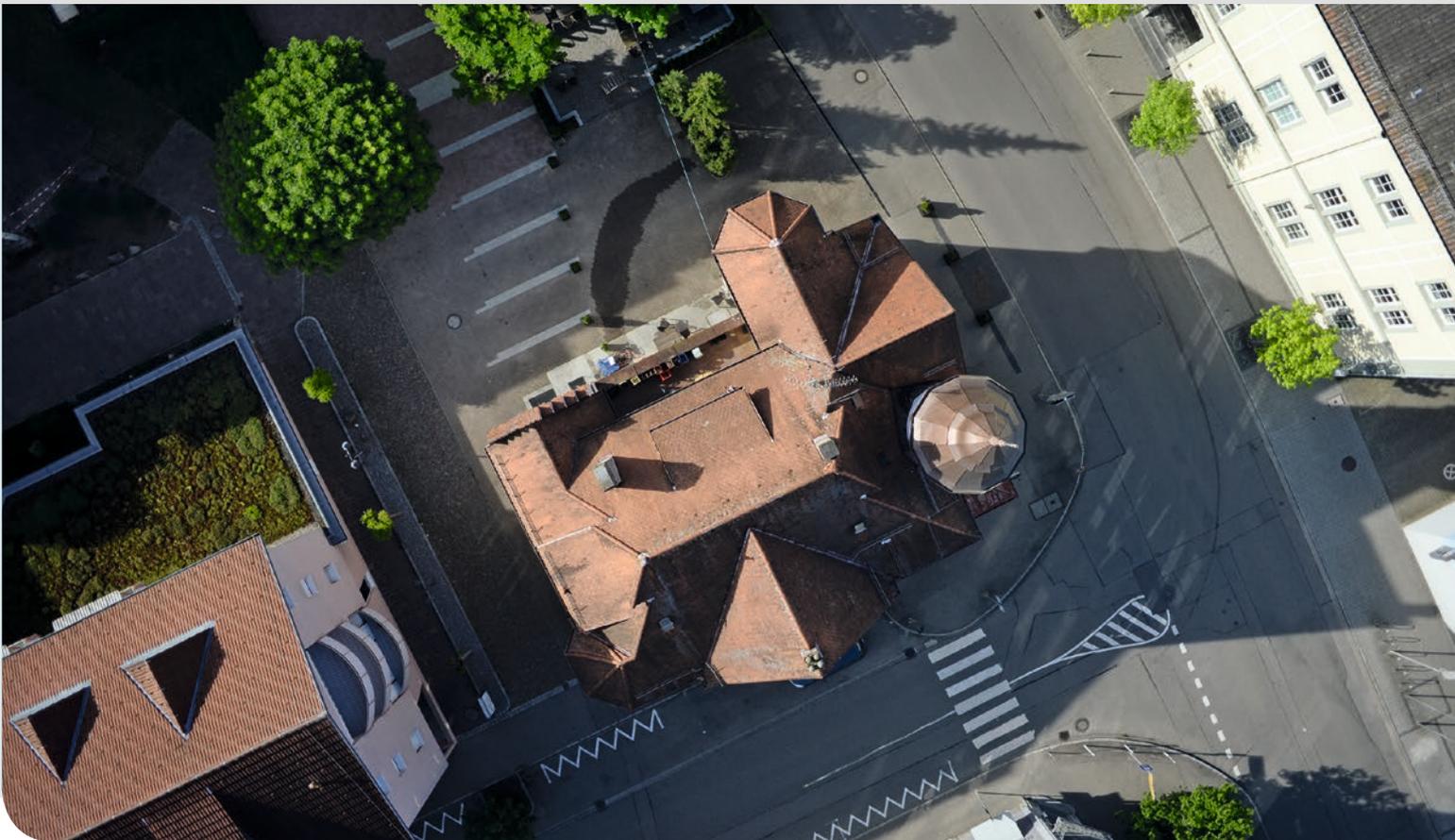
The use of the UAV system and more than 30 projects implemented by the IngenieurTeam GEO GmbH prove that the UAV system delivers excellent results for surveying in the area of engineering services. The as-built documentation and the creation of ortho-photos as seen in this project are merely two possible areas of application. Other applications are

quite possible in the future. For example, building and property inspections as well as large-scale monitoring and inspections are also conceivable. It is also possible to carry out flights in GNSS-denied areas for aerial surveys, such as in large halls.

Similar to laser scanning, the processing of data and the resulting point cloud allow for diverse finishing processes and optimally complements classic methods of surveying.

Due to substantially improved software programs in the field of photogrammetry like Agisoft Photo Pro, one can certainly speak of a renaissance in the area of photogrammetry. Large amounts of data can be collected and analysed in a short time, quickly delivering 3D data to the client and simplifying the decision-making process much more effectively than a large piece of paper with plotted content, which gives only a crude depiction of what actually exists on the ground.

Despite upgrades in computing capacity, such as larger memory and powerful graphic cards, the processing of very large amounts of data is currently a problem due to longer processing times. The quantity of data and dimensions submitted to the customer should be discussed in advance and pre-established



■ **Client requirement fulfilled: exact geometries of the roofscapes, captured with the Aibot X6.**

as much as possible. Ultimately, the end customer and user must be able to use their data according to their needs and applications.

In future projects, the use of UAV and photogrammetric data processing for obtaining 3D data will efficiently and effectively complement traditional methods. The rapid development of UAV systems is supported by the principles of surveying and geoinformatics.

As professionals in the geo-industry and in order to provide clients with maximum added value, surveyors are committed to provide clients with the best advice

possible, to perform work with the highest-quality sensors and methods, and to optimally analyse and to refine the data. ■

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## IngenieurTeam GEO GmbH

The surveying office is headquartered in Karlsruhe and offers services in engineering surveying and hydrography (water measurement). Since 2014, the company has supplemented this offer for a further future-oriented business field, the survey with UAV systems. IngenieurTeam GEO GmbH sees the

enhancement of data collection using UAV systems as the right decision for future success. The engineering office is equipped with the latest measuring and data processing systems.

[www.it-geo.de](http://www.it-geo.de)

# Sustainably maintain and protect trees using GIS

by Johannes Grösbrink

**TyssenKrupp Steel Europe AG and its predecessor companies have been active in their core location of Duisburg for more than 120 years. Together with its subsidiaries, the company supplies a wide range of steel processing sectors. The individual locations, therefore, set benchmarks in terms of environmental impact, but not just in Germany. The company is active in the sustainable preservation of the environment. In this context and due to statutory requirements, two years ago the task was formulated to complete the entire tree population of Duisburg in the company's GIS using a field comparison process and other valuable data for preservation and care.**

The goal is to achieve and maintain a homogeneous and scenically presentable tree landscape in an area of 800 hectares (2,000 acres) at the company

campus. This project will also make it possible to document replacement plantings. A prescribed tree injury assessment and appropriate tree care is planned to be reviewed yearly. In addition, the devastating storms of 2014 made it evident that the security of the trees at the campus is vitally important. The data will be used as a tender basis for these measures and will include the an updated version of all the green spaces on the premises. Exact figures pertaining to paved areas and green areas will be made available to the appropriate departments for the determination of drainage charges and for awarding contracts for green care measures. All supports for large industrial pipe systems located on the factory premises including pipeline routes and appropriate support numbers are recorded for the company's GIS.

## **The right equipment saves time**

To perform this task economically and to complete it in a reasonable period of time, it was decided to work with the graphic field book FX Collector made



by Frox IT Factory before the start of the project. The hardware platform consists of a Panasonic Toughpad FZ-G1 attached with a Leica Zeno GG03 GNSS SmartAntenna and a Leica CS25 GNSS plus with helix antenna.

The objects to be recorded were identified with the highly accurate Leica Zeno GNSS SmartAntenna and composed using the numerous FX Collector available drawing functions. In addition, mixed methods were used; the rapid interaction of the FX Collector was used in combination with the Leica Zeno GNSS SmartAntenna. This method quickly provides position data auxiliary points, which are then used to construct hard-to-reach objects on the tablet.

All background data (aerial photographs, Web Map Service, CAD data) were stored in geo-referenced format in the FX collector. Examining surfaces and existing trees, measurement of the pipe supports as well as the orientation of the location were thus

greatly simplified. It was thus possible to create the extensive dataset quickly and in high quality.

“ThyssenKrupp Steel Europe AG is totally satisfied with the combination of the FX Collector, Leica CS25 GNSS plus and Leica Zeno GG03 SmartAntenna,” said Klaudius Drass, Dipl.-Ing Geography at ThyssenKrupp Steel Europe AG, and the person responsible for the in-house GIS. “Efficiency was increased by about 30 percent compared to conventional field comparison method.”

### **High mobility and data storage in the cloud**

It was advantageous to work with the graphic field book, especially in the densely wooded areas. It's the most efficient method for allowing continuous on-the-spot visual checks to be made regarding the completeness of the data. The advantage of the system is the high degree of mobility and the fact that the system can be operated without cumbersome field sketches, additional maps or additional equipment.



In particular, the Leica CS25 GNSS plus in combination with the helix antenna offers reliability, ease of use, mobility, and delivers sub-decimetre accuracy. The Panasonic Toughpad FZ-G1 with the Leica Zeno GG03 SmartAntenna on the pole was used in all other areas where higher accuracy was required.

The project was backed up on site to the cloud daily so preliminary results could be available immediately to office staff. FX Collector's Session feature was

used in this context to allow the data to be exported on a daily basis without having to create a new project each day.

The results were provided in digital form. Trees and pipe supports were exported using FX Collector's table-driven interfaces so that they could be read directly into ThyssenKrupp's GIS system. The changed green spaces as well as the new green spaces were replaced or supplemented in GIS.

"The weatherproof CS25 GNSS plus is resistant to rain, wind and dirt. The computer and the antenna were easy to carry throughout the day," said Drass. "The batteries lasted all day and were fully charged by morning due to the short charging period. The 'fixed' solution was achieved extremely 'quick' - there was hardly any waiting time."

#### **Reduction of office work to a minimum**

A large portion of the planning preparation was conducted in the field, reducing post-processing in the office to a minimum due to the standardised high quality of recorded data. The office staff was able to import the data quickly and easily into the client's GIS. This further emphasises the efficiency of the entire process.

"The Leica CS25 GNSS plus offers a good platform for the FX Collector. The Leica Zeno GG03 SmartAntenna was connected with the two tablets via Bluetooth. Measuring was done quickly and easily, and a fixed position was returned within a short period," said Drass. "Shaded areas were processed quickly using measured auxiliary points via GNSS and the numerous design features." ■

#### *About the author:*

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# At an unknown depth

by Andreas Barmettler

Since 1928, there has been a mine tunnel that was excavated by a cement company for material extraction in the Hausen municipality of the Swiss canton Aargau. With the creation of the approximately 800-metre (2,625-foot) long tunnel, a maintenance obligation encumbrance on the company's parcel of land was also recorded in the land register. Just four years later, the cement plant was closed down again and stood empty until its takeover by a chemical company. In the course of time, the entrances to the tunnel were filled with concrete by the new owner and the tunnel was forgotten. In connection with a possible sale of the land and associated encumbrance transfer, the owner wanted to learn more about the condition of the mysterious tunnel. Since the basic plans could no longer

be found, the tunnel had to be resurveyed. The Leica Nova MS50 MultiStation proved to be the perfect instrument for this assignment.

The only remaining access to the tunnel was through a 15-metre (50-foot) deep and only 60-centimetre (24-inch) wide vertical shaft. During the first site inspection with a drainage specialist, it emerged that there was no oxygen present, even at the bottom of the shaft. Additional challenges appeared during a further investigation. Part of the tunnel was up to 30 centimetres (12 inches) under water and at one point buried up to 80 percent with clay and mud. Furthermore, radio communication did not function over the entire length of the 800-metre (2,625-foot) tunnel, which reduced safety significantly. In addition, the tunnel had three cavern-like breakouts that were partly buried. They could have served as loading stations and turning places for the material trans-





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■ Unlike normal work environments, surveying of the tunnel needed special equipment.

portation railcars. The two ends of the tunnel were never fully developed and remain raw excavations to this day.

### **Safety preparations for the tunnel's thin air**

These extreme conditions made the already difficult survey work into a true logistical and safety-related challenge. Like an expedition, an emergency operational plan was even developed by the rescue service for the three Trigonet AG employees and a BSF Swissphoto employee. In addition to mining equipment with hardhats, flashlights and radios, safe entry, exit, material transport and, above all, the necessary oxygen supply with breathing protection had to be ensured. The entire measuring operation was under enormous time pressure because the air in the tunnel was only sufficient for six hours.

### **Transferring coordinates down to the tunnel requires high precision**

The desired accuracy was specified as 5 centimetres (2 inches) for both position and height. A control network, based on the fixed points of the official survey, was first measured above ground and three control points were established at the top of the vertical shaft. A free station was calculated down in the tunnel using these three points in order to transfer the position into the shaft within an accuracy of 1 millimetre (0.04 inch). Then, an open traverse

survey with centerings, each established with one lateral control point (reflector bolt) was measured at each of the stations. Depending on the situation, the aiming distances varied between 30 and 200 metres (100 and 660 feet). During traversing, approximately 70 additional profiles were recorded when the tunnel geometry changed. At both ends of the tunnel, the undeveloped portion was scanned with the Nova MS50 at a vertical resolution of less than 1 centimetre (0.4 inch). The profiles were generated later with CAD.

A gyroscope, the Gyromat2000, was used for precise transfer of the orientation of the above-ground network into the tunnel. These measurements were carried out by BSF Swissphoto. Each measurement on the above ground 130-metre long (425-foot) reference distance took one hour. All of the survey equipment was then lowered into the tunnel and a forward-and-back survey was carried out. Due to the tunnel geometry and because the water was too deep at the bottom of the shaft, the orientation in the tunnel had to be transferred about 300 metres (980 feet) from the vertical shaft.

Unfortunately, the total station on the gyroscope was non-robotic and the telescope did not have an integrated camera to transfer the image and cross-hair on the display. So the measurement of target points had to be carried out manually. The observer



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■ The MultiStation allows accurate surveying without the need of aiming targets through the telescope.

had to wear a special breathing mask when looking through the ocular.

This problem did not arise in the subsequent recording of the tunnel over its entire length and the break-outs with the Leica Nova MS50. The integrated camera and scanning function are ideal for these kinds of measuring tasks.

### On schedule, to specification

The calculation of coordinates took place, combined from all measurements and based on the fixed points of the official survey. At the end of the tunnel, it was possible to achieve a measurement accuracy of 4 centimetres (1.6 inches) horizontally and an elevation accuracy of 2 centimetres (0.8 inches), thus meeting the client's specifications. Further measurement processing for transverse and longitudinal profiles was carried out using CAD. Several profile points had to be reconstructed, particularly in the three cavern like breakouts that were inaccessible due to burial.

Due to the time constraints, fewer setups than desired were carried out. The height differences to the terrain also had to be calculated. The swisstopo surface terrain model (swissALTI3D), which does not integrate houses and infrastructure, served as a basis. At about 12 metres (39 feet), the cover is at a minimum in the area of the vertical shaft and, with increasing length, it rises to a massive 100 metres (330 feet).

### Leica Nova MultiStation reduces measuring time

The mystery of the forgotten tunnel has now been revealed. It was possible to carry out the tunnel survey safely despite enormous time pressure and physical effort. Use of the gyroscope also made sense in order to reliably achieve the specified horizontal accuracy.

Use of the Leica Nova MS50 MultiStation has proven its value as a universal, accurate measuring instrument. It has a high rotating speed, an extremely helpful scanning function, an illuminated control panel and an integrated camera. And it was particularly useful because the crosshair and image of the integrated telescope camera were transferred to the display, so the breathing mask did not interfere when measuring. That the measurements of the 800-metre (2,625-foot) long tunnel could be safely completed within six hours is undoubtedly also due to the MultiStation. ■

*About the author:*

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# Scanning a building in motion

by Angus W. Stocking, PS

**Architects, planners, contractors and other infrastructure professionals have been using laser scanners to create high-quality 3D documentations of buildings for many years so it would seem that there wouldn't be much new to write about in architectural scanning. But James G. Davis Construction Corporation (DAVIS) of Maryland proved that to be wrong after scanning a four-story, 880-ton brick building in Washington D.C., and then scanning it again a week later, discovering that the building had moved 34 feet!**

This was according to plan, thankfully. The building in question was at 639 New York Avenue, built in 1891. It's a historic building calling for scrupulous preservation. But the building is also subject to history and was part of a massive downtown development contracted by DAVIS. To work with the rest of the development plans, 639 New York Avenue really needed to be beside itself. "The developer has a niche in this area, working with historic properties," DAVIS Vice-President of Integrated Construction

Chris Scanlon explains. "In this case, several buildings were affected; on some, just the facade needed to be preserved. But to work with the overall development, two buildings had to be entirely preserved, and moved."

## **Providing crucial insights early on**

The initial scan was routine; just three setups with a Leica ScanStation C10. The detailed information provided was invaluable and could not have been obtained with conventional survey techniques. "For one thing, we learned that the building was even farther over property lines than we thought," says Project Superintendent Doug Bauer. "Four inches of encroachment into public space was known, but the scan showed a bulge in the brick facade that was actually eight inches into public space. Learning about that after the move would have been a big deal."

DAVIS crews and office staff used Leica Infinity and Leica Cyclone software solutions to import and manipulate point clouds. The main analysis tool, heat maps, was used to identify deformations from plane. "Within Cyclone, we can easily project planes,

from a property line for example, and then generate heat maps, showing us deformations relative to that plane," Senior Field Engineer Mike Cumberland explains. "It's a really nice feature, giving us critical information quickly."

The building's deformation data helps us to add bracing as needed before a move, to facilitate removal and accurate replacement of building sections, and to account for property line issues, as described above. The heat maps analysis also discovered another deformation in a sidewall, a bulge that could have been a big problem. "We were moving this building 34 feet laterally onto a new pad within a few inches of an existing four-story building," explains Cumberland. "In fact, pilasters on each building were projected to be within two inches of each other—so when we learned that our building's pilasters were out of plumb, leaning more than an inch past vertical, we realized we had a potential issue. But a scan of the neighbouring building saved the situation; since that building leaned inward about five inches in the corresponding area of the sidewalls."

### Tracking the move for accuracy

During the actual move, DAVIS used a Leica Nova MS50 MultiStation to track the building and compare its path to an ideal baseline. "We knew where the building was, from as-builts, and we knew where it needed to be moved," Bauer says. "Since there are five jacks actually pushing the building, we were able to make adjustments mid-course." During the event, the initial track of the push would have left the building three inches out of square. By adjusting the jacks we could bring it back onto the desired course.

Several prisms were mounted on the moving building and shot periodically. But Cumberland says next time, the process will be done differently. "We'll mount prisms for the next move, but this time, the Leica Nova MS50 tracked continuously, giving us even better real-time information."

### Scanning becoming standard in construction

"When we formed our Virtual Construction Group six years ago, the investment in the Leica ScanStation C10 was a big leap of faith," says Scanlon. "We did have a couple of use cases, including the Constitution Center [at over 93,000 square metres (1 million square feet), the Center is D.C.'s largest privately



■ The house is moved on jacks to its new location.

owned office building], which justified a large portion of the cost, but after that we weren't sure there would be enough scanning to dedicate a crew to it. But in fact, high density surveying quickly became standard for us – it's just more efficient, and field crews caught on quickly."

As laser scanners become more common, it seems that all their applications have been discovered. But DAVIS Construction demonstrated by successfully and accurately moving an 880-ton building, surveyors and contractors might only begin to realise what this remarkable technology is capable of achieving. ■

Building move video: <https://vimeo.com/125509745>

This article is adapted from the original, published in *American Surveyor* edition July 2015. For more information please visit <http://www.amerisurv.com/>.

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# 3D laser scanning: Anticipating the uncontrollable

by Vicki Speed

**When the magnitude 6.9 Loma Prieta earthquake struck Northern California Oct. 17, 1989, the San Francisco-Oakland Bay Bridge (SFOBB) system, known locally as the Bay Bridge, was one of the major man-made structures that sustained damage. A section of the east span's upper deck collapsed onto the lower deck, killing one person and forcing a month-long closure of one of the most important transportation arteries in the region.**

**California Department of Transportation (Caltrans) officials and project partners needed to know how much movement had occurred across the original east span due to the collapsed and damaged deck sections. Unfortunately, as-built measurement records of the Bay Bridge and the other major bridges in the Bay Area did not exist, so obtaining a quantitative assessment on the entire original east span truss section deformation was not possible. It was a dilemma that Caltrans District 4 Right of Way Field Sur-**

**veys and District Office Chief Nelson Aguilar, PLS, was determined to prevent in the future.**

As construction began in 2002 on a new 3,1-kilometre (1,9-mile) east span of the Bay Bridge, a ground-breaking technology was beginning to draw interest in the surveying and engineering community. 3D laser scanning, pioneered by Ben Kacyra as High Definition Surveying (HDS) under the brand Cyrax (acquired by Leica Geosystems in 2001), promised to revolutionise as-built documentation by using lasers for 3D reality capture.

In April 2008, during the preliminary work on the Bay Bridge South-South detour project, the Caltrans team used an early version of the Leica ScanStation laser scanner to capture areas under the deck and surrounding areas of the bridge. These early successes set the stage to complete the visionary project conceived by Aguilar – a detailed, survey-accurate digital as-built model of the entire Bay Bridge, an effort that would come to be known by the District 4 survey team as “The Erskine Project”. “A key part of the survey project was to ensure that the structures



© Rebecca Boyer

designed by consultants and built by the contractor were done per design and would behave as expected in a major seismic event," Aguilar says.

### A tight timeline

Since traffic was still using the original east span structure, the new east span was easy to scan. A planned closure of the bridge over Labor Day weekend in 2013 would provide the best opportunity to scan the west span decks. To manage the work, Caltrans looked to C.J. Vandegrift, PLS, senior transportation surveyor and West Bay Branch chief, who had managed the Caltrans survey crews for the east span project.

The planned closure was from Wednesday night at 10 pm to early Tuesday morning following Labor Day. On Monday late morning, an aerial photogrammetry team flew over the bridge site to gather LiDAR data from the air. Ground crews performed mobile scanning on Saturday morning, Sunday evening and Monday on both spans. The Caltrans crews used three Leica ScanStation C10 laser scanners to scan the lower deck of the western span, the underside of

both spans, and the self-anchored suspension (SAS) bridge upper deck through the lower YBI tunnel.

All three scanners ran continuously for at least 12 hours a day. Meticulous planning allowed much of the work to proceed smoothly, but there was one challenge the team hadn't foreseen: extreme vibration. "We anticipated some thermal expansion and vibration, but nothing like what we experienced," says Vandegrift. "Even without vehicles on the bridge, the atmospheric vibration and subsequent deflections were significant."

To achieve maximum redundancy, the team added total stations and GPS. Multiple GPS measurements were taken at night on the decks of the centre spans where multipath interference with the cables was not observed. GPS measurements were also taken at the north and south corners on the top of each SFOBB tower, stable portions of the structure that were used for control. Despite the challenging conditions, the data from the stationary terrestrial laser scanners met survey-grade accuracy requirements, and the project was completed on schedule. In fact,



work was finished faster than anticipated, allowing Caltrans to open the new east span of the bridge to traffic about seven hours earlier than planned.

### Powerful 3D information

For Vandegrift and the other professionals on the team, the project provided crucial insights on the practices and procedures required to ensure a successful outcome with laser scanning. "The most important thing to remember, especially on a project this size, is the need to set control," Vandegrift says. "Many contractors think they can hop off with a receiver and come up with a Continuously Operating Reference Stations (CORS) – that won't work on a project like this, and scanning ups the ante. Contractors must calibrate off established control or they won't have the same values. With scanning, if a project team uses the wrong control, they will gather data that is exponentially inaccurate."

Surveyors and contractors must understand that to create the model from a scan is simple – but for it to be accurate and calibrated to local horizontal and vertical datums, they must look deeper into the surveying methodology and associated errors. They must understand the scaling from the grid reference system back to the ground, particularly in an area like San Francisco, where the earth shifts continuously.

"I'm extraordinarily proud of this project," says Vandegrift. "When it comes to scanning, if you get the

control tight, you get the best product with the least amount of field time.

"On many projects, uncontrolled changes can occur, so the contractor ends up needing more data," she adds. "Surveyors often have to deal with more trips to the field or datum changes. But with scanning, we know once we have a model, the folks back in the office can mine data from it without more field work. We could not have created this data intensive, high accuracy model in such a short amount of time without cutting edge technology such as 3D laser scanning. We can achieve detail that conventional surveying methods simply can't and have raw data right down to the bolts and rivets. That's powerful." ■

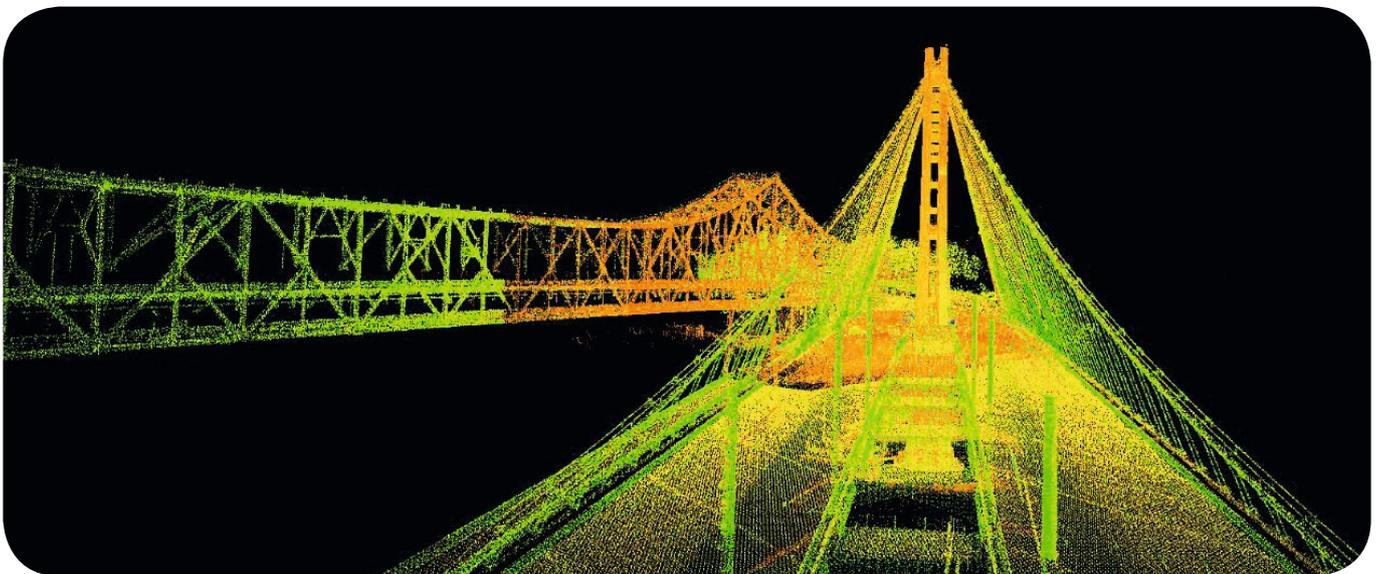
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*This article is adapted from the original, published in LiDAR News Vol5 No1. For more information please visit [www.lidarnews.com](http://www.lidarnews.com).*

#### About the author:

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■ Detailed point cloud of the San Francisco-Oakland Bay Bridge.

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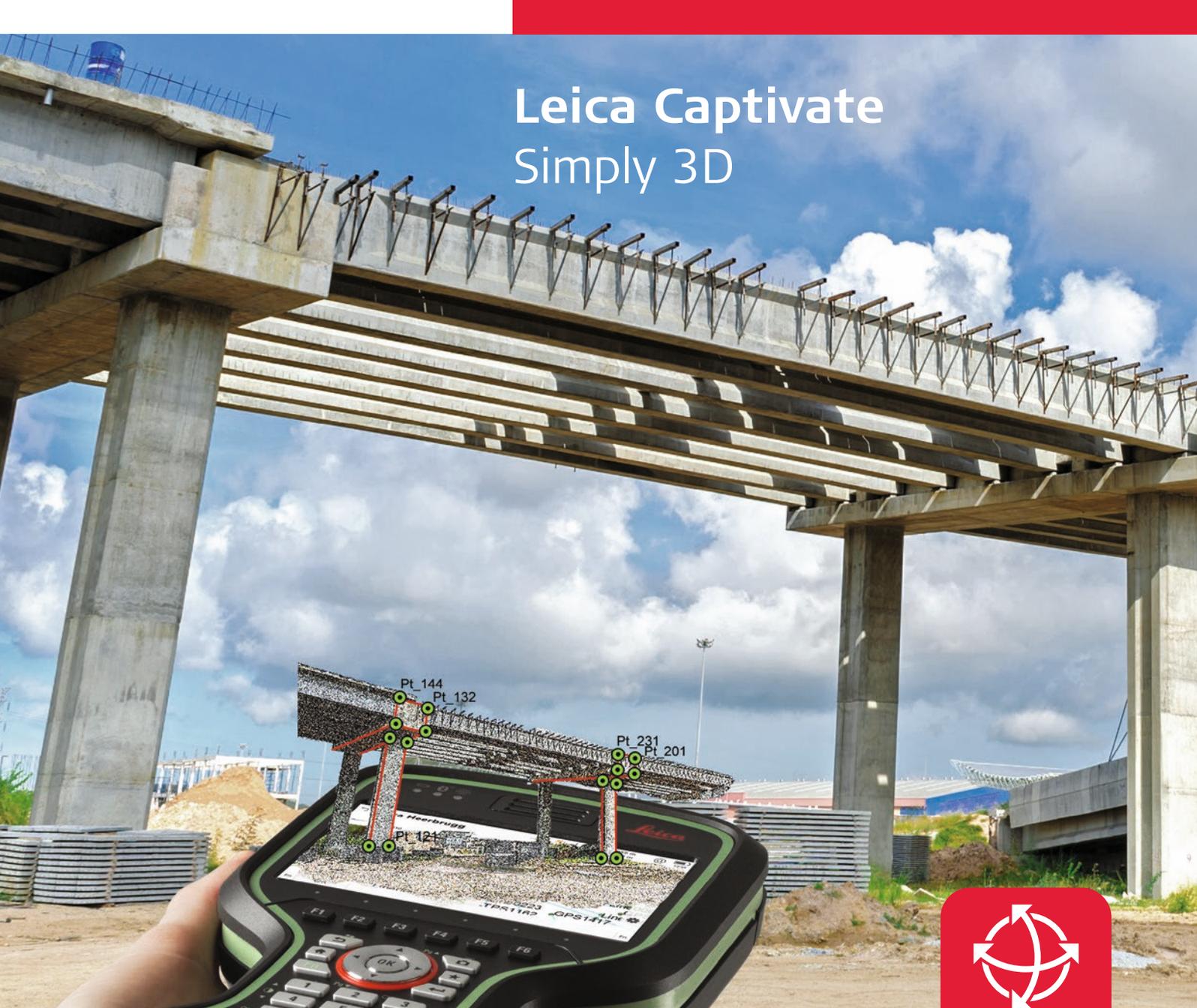
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