ISSUE 4 | DECEMBER 2023
ISSN: 2581- 4613
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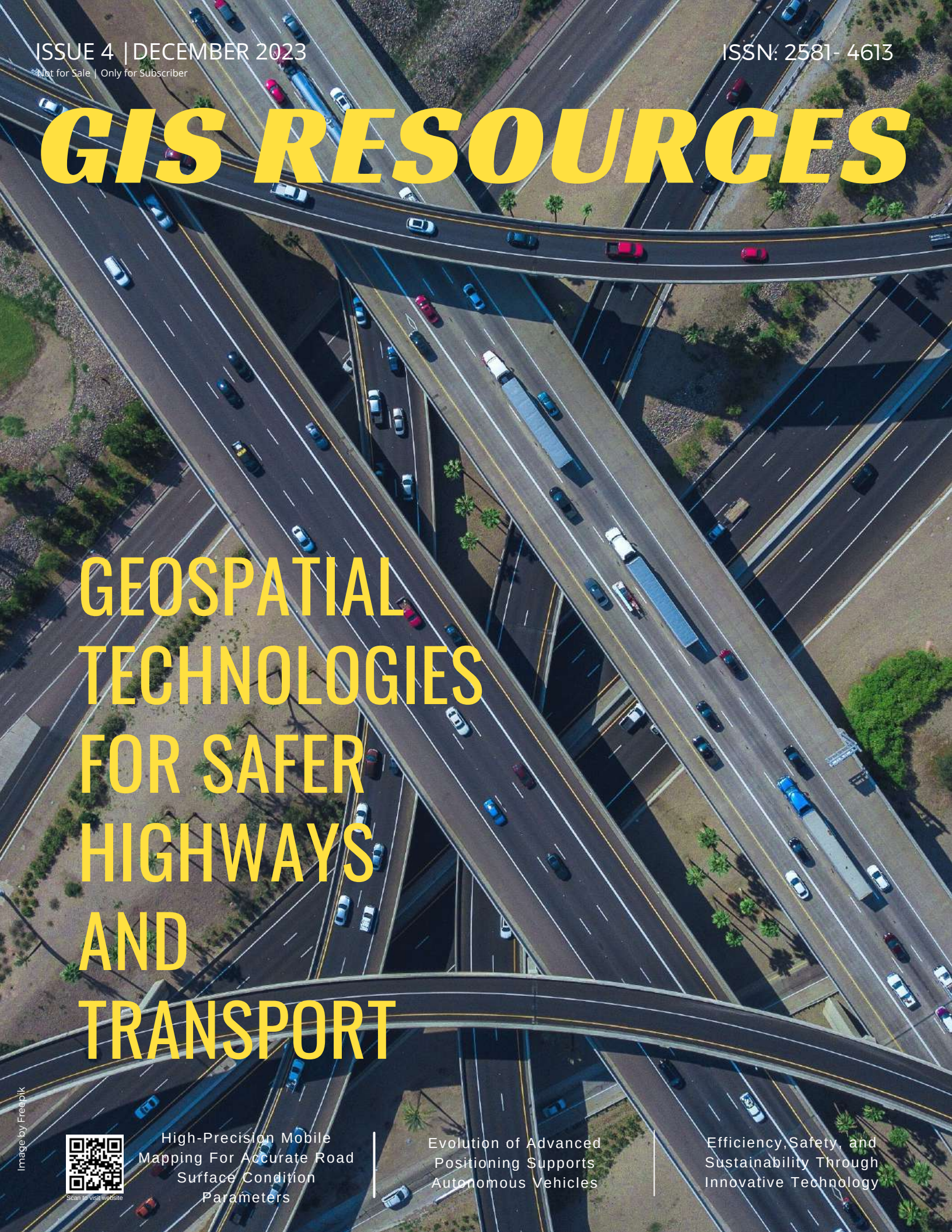

GEOSPATIAL TECHNOLOGIES FOR SAFER HIGHWAYS AND TRANSPORT

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High-Precision Mobile Mapping For Accurate Road Surface Condition Parameters

Evolution of Advanced Positioning Supports Autonomous Vehicles

Efficiency, Safety, and Sustainability Through Innovative Technology

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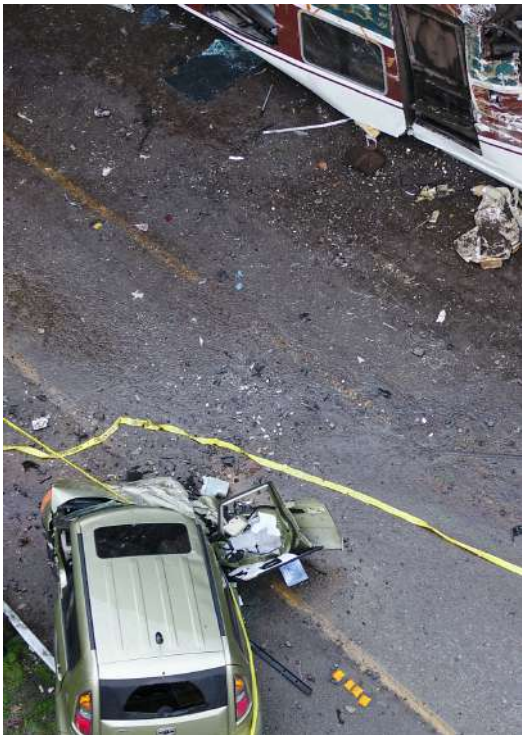

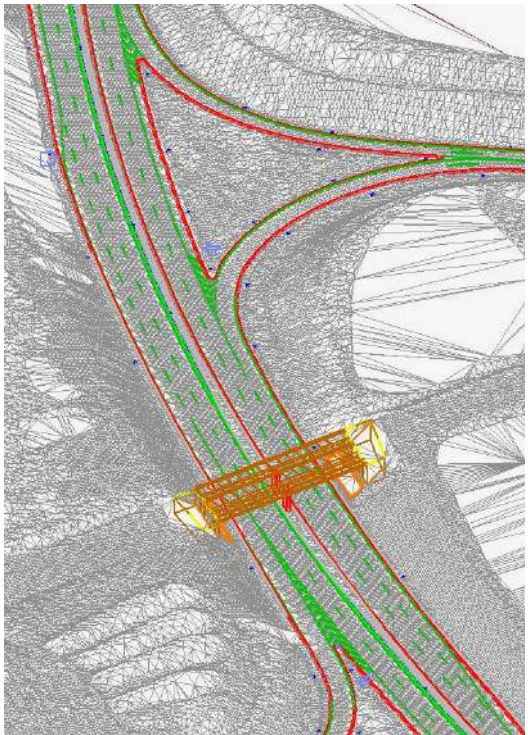

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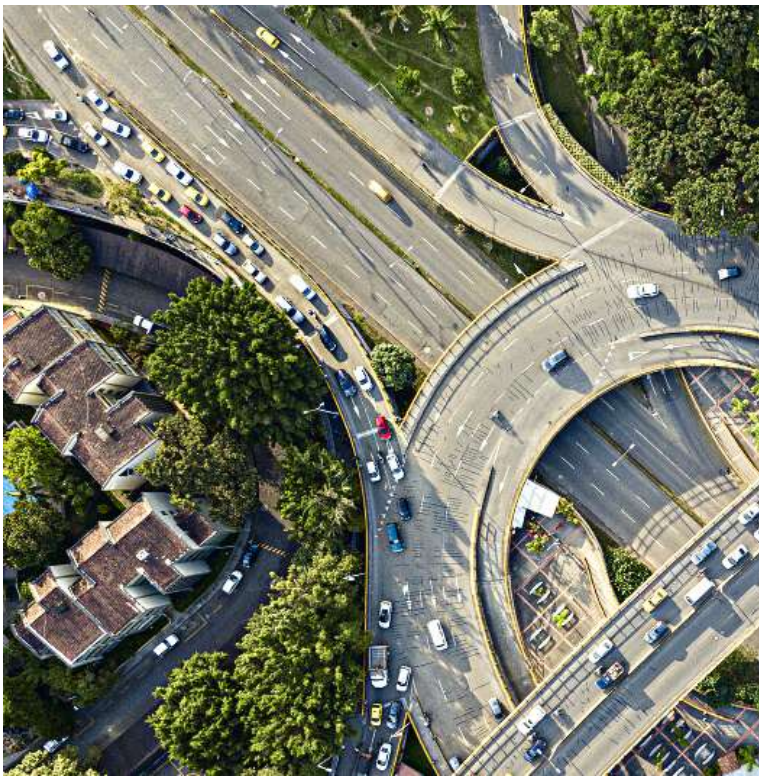


Editor's Note

For centuries, humans have traversed roads, forging pathways across mountains and deserts. But as the world hurtles towards an interconnected future, the demands placed on our transportation systems are growing exponentially.

Geospatial technologies are emerging as a crucial tool in ensuring the safety and efficiency of our highways and transport systems. The integration of Geographic Information Systems (GIS), Global Positioning System (GPS), Light Detection and Ranging (LiDAR), Advanced Driver Assistance Systems (ADAS), and remote sensing has ushered in a new era of precision and intelligence in the realm of transportation.

GIS, the bedrock of geospatial technologies, provides a comprehensive platform for mapping, analyzing, and visualizing spatial data.

LiDAR, with its ability to capture high-resolution three-dimensional data, has become instrumental in creating detailed topographical maps and detecting subtle changes in the environment.

Remote sensing, through satellites and aerial platforms, offers a bird's-eye view of transportation networks. This technology enables the monitoring of traffic patterns, identification of road obstructions, and assessment of environmental factors affecting transport systems.

The advent of Advanced Driver Assistance Systems (ADAS) has brought about a paradigm shift in vehicular safety. Utilizing a combination of sensors, cameras, and radar, ADAS technologies enhance driver awareness and assist in avoiding collisions.

As we embrace the era of smart transportation, the synergy of these geospatial technologies holds the promise of safer highways and more efficient transport networks. Governments, industries, and researchers must collaborate to harness the full potential of geospatial technologies to create a future where the journey is not just about reaching the destination but doing so seamlessly, securely, and sustainably.

Innovative surveying technology makes the process of on-site levelling more accurate and efficient.
Copyright: STARBAG

Efficiency, Safety, and Sustainability Through Innovative Technology

By Renata Barradas
Communications Manager
Leica Geosystems

STRABAG leverages innovative technology to make work more efficient, improve worker safety and drive sustainability in urban areas.

Geospatial technologies and surveyors play a crucial role in developing infrastructure and green transportation projects to make cities more inclusive and resilient. Utilising advanced surveying tools, surveyors can accurately and efficiently capture data essential for modernising infrastructure. Geospatial data is key for sustainability projects including making cities safer for cyclists, redesigning bus stops to accommodate longer buses or improving accessibility for individuals with disabilities. The use of geospatial technologies and the continuous innovation in surveying equipment streamlines the urban development process and contributes to creating sustainable, equitable, and resilient cities with improved infrastructure and green transportation systems.

Building more sustainable, equitable, and resilient cities requires planning, constructing, and maintaining infrastructure. This includes a focus on smart mobility and green infrastructure. Across the world, cities are transforming this vision.

How Geospatial Data Helps Build Resilient, Inclusive Infrastructure

The transformation of cities into more sustainable, inclusive, and resilient environments requires the collaboration of various stakeholders, including surveyors like Dipl.-Ing.

Lothar Lyschik. With nearly four decades of experience, Lyschik leads the surveying activities of the Traffic Route Construction Division of Munich and its surrounding communities at STRABAG AG, the No. 1 traffic route construction company in Germany.

Toward A More Inclusive and Greener City

Lyschik and his team at STRABAG AG have successfully completed three recent projects in Munich, including the reconstruction of a bus stop, the redesign of public squares, and the conversion of intersections for improved traffic routing.

The bus stop was redesigned to accommodate longer towing vehicles and to provide easier access for individuals with mobility limitations, with an appropriate height for those with disabilities. The team also helped enhance Munich's public squares by adding more green spaces, comfortable seating, and a more harmonious aesthetic that prioritises pedestrian accessibility. To improve safety, STRABAG also converted intersections to better accommodate pedestrian and bicycle traffic, eliminating barriers and thresholds for individuals with disabilities. Cyclists, on the other hand, will benefit from a level crossing at the intersections.

Big Projects, Little Time

Lyschik, an experienced surveyor with many years of experience, has surveyed numerous large-scale road reconstruction projects. The usual completion times range from a few months to two years, but to minimise the disruption to traffic, the construction work at intersections and other construction sites is conducted in sections with limited time windows. To ensure safety and timely completion, STRABAG AG held weekly meetings to regulate the construction process and collaborate with other units.

Reliable Partners in a Dense Traffic Area

When working in dense traffic areas, surveyors use state-of-the-art surveying equipment that helps them do the job safely within the short timeframes given.

Surveying innovations that did not exist a few years ago is a great advantage, especially for

Figure 1: Game-changing solutions ensure accurate measurements and avoid typical errors.

Figure 2: A versatile, survey-grade GNSS RTK rover with visual positioning helps surveying professionals to capture an environment in images quickly and decide which points to measure later.

"We are only given a very, very small time window for certain conversion measures because individual traffic should be restricted as little as possible. Safety is a top priority for us, so securing the construction site is a crucial part of the construction process. We aim to prevent any accidents from happening during construction."

Lyschik

documentation. New surveying technology enables measurements on uneven surfaces, from difficult positions, and from any angle. This facilitates and speeds up measurements, for example, in areas around subway shafts or in traffic islands that are equipped with signs or light signalling systems. In places with enough visibility to the sky, surveyors use a satellite-based navigation system to map construction projects without risking line-of-sight interruptions from traffic.

Figure 3: Surveying crews have become smaller over time and technology has transformed how surveyors work.

Field and Office Surveying Software That Fits City Demands And Regulations

Lyschik precisely recorded all details of the traffic surface, including carriageways, footways, cycle lanes, and traffic islands, with the accuracy and format required by Munich's template catalogue. Complex data processing is enabled by surveying software that collects survey data from different instruments and generates precise 2D views and 3D models. Geospatial office software, meanwhile, enables continuous data exchange between the field and the office, allowing teams to work efficiently with real-time data.

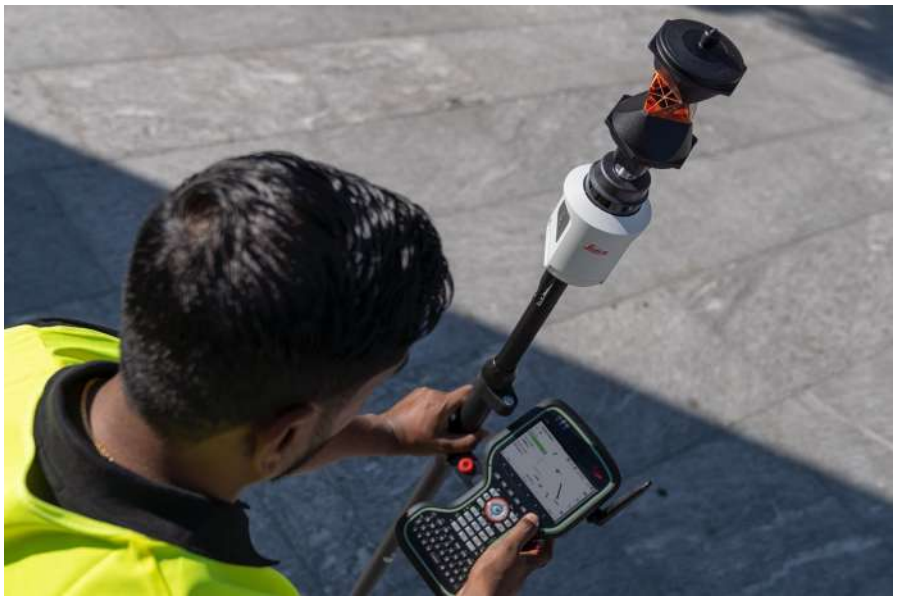


Figure 4: Geospatial software enables continuous data exchange between the field and the office.

Leveraging Geospatial Technology

With nearly four decades of experience, Lyschik has witnessed how surveying crews have become smaller over time and technology has transformed how surveyors work.

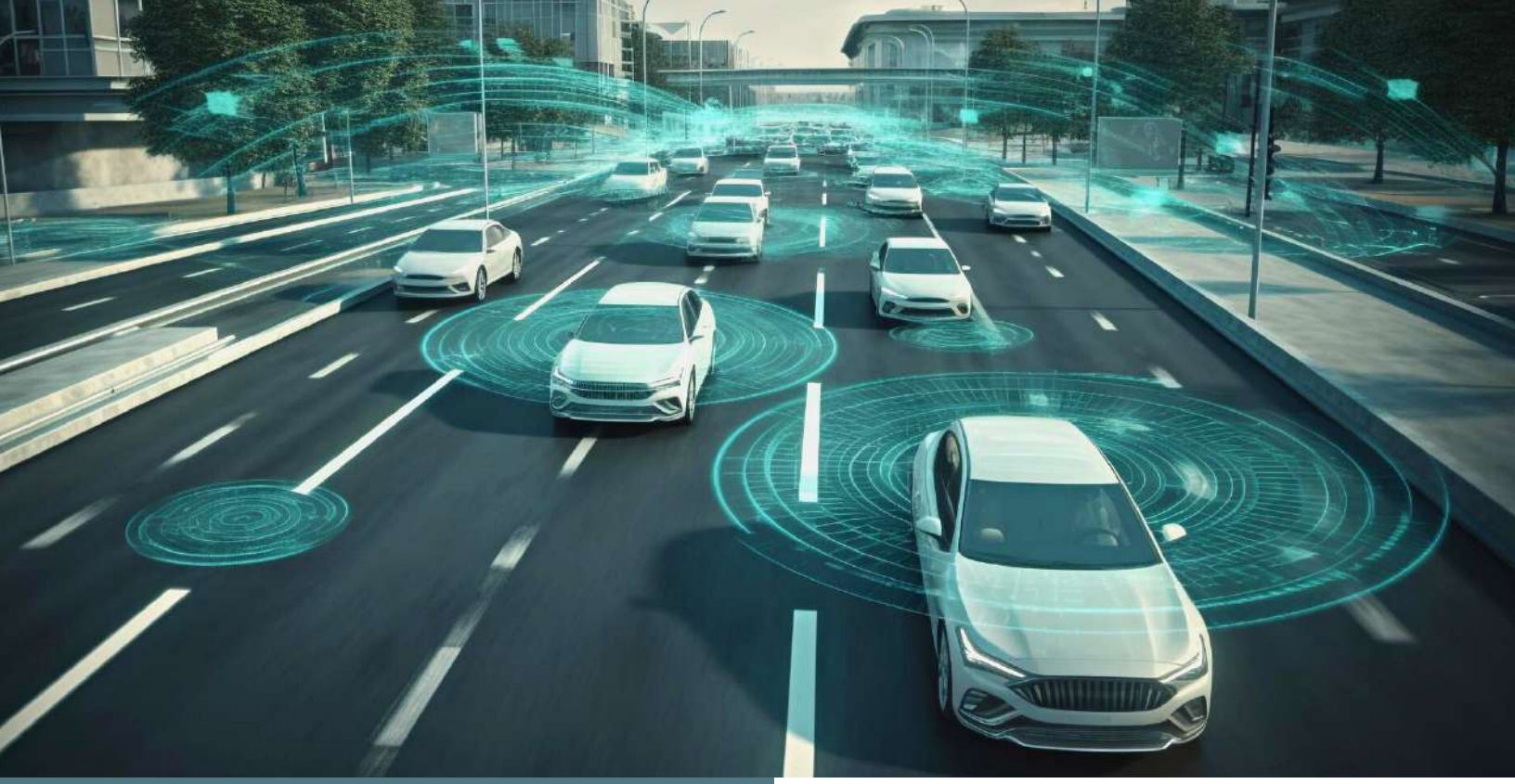
Finding coordinates in new areas used to take up to one day or even longer. Thanks to GPS or GNSS positioning, the same can now be done in much less time. Lyschik has personally experienced the advantages of these innovative tools, which have simplified his work by eliminating the need for manual surveys. Utilising cutting-edge technologies like GNSS in combination with image capture has not only saved time for Lyschik and his team but has also made their work more manageable while minimising exposure to potential hazards.

When new innovations emerge in surveying equipment, STRABAG AG proactively integrates them into its daily workflows to improve efficiency, expand its service offerings and enhance safety measures.

Construction firms such as STRABAG play a pivotal role in transforming cities into sustainable, inclusive, and resilient environments. Technological advancements enable surveyors to complete projects with greater accuracy and speed, streamlining the construction process and creating better infrastructure for all.

"Surveyors have become lone wolves. When I was a student, the measuring team still consisted of three people. Over time that has been reduced to two, and I would say that with the one-man station, we all work alone now."

Lyschik



Evolution of Advanced Positioning Supports Autonomous Vehicles

By Paola Gonzalez
Strategic Technical Marketing
Trimble Autonomous Navigation Solutions

Kevin Andrews
Strategic Marketing Manager
Trimble Autonomy

Challenges around autonomous technology, regulations and public trust are common to both long-haul trucks and heavy construction machinery, even though the applications and operating environments are very different. Over the past several decades, Trimble has developed advanced positioning technology for the construction industry that is now paving the way for successful integration of autonomous solutions in other industries. The evolution of precise positioning has laid the groundwork for semi-autonomous solutions in operation today and for fully autonomous activities in the future.

Location, Location, Location

The combination of ground- and satellite-based Global Navigation Satellite Systems (GNSS) and Inertial Navigation Systems (INS), working in tandem with LiDAR, radar and cameras mounted on vehicles, creates a comprehensive suite of tools that not only determine a vehicle's precise location but also contribute crucial data for real-time decision-making. The result is better performance, increased efficiency, reduced risk to operators and lower costs.

The journey towards semi-autonomous solutions has seen significant progress in today's vehicles. Early forays into incorporating positioning technology began 30 years ago with off-road mining and construction trucks, as well as agricultural machinery. In these closed environments requiring repetitive tasks, positioning equipment demonstrated that vehicles could safely operate within set boundaries without constant human intervention. During this period, the industry gained insights into how sensors

could “see” people and other vehicles, setting the stage for more complex applications.

As we look to the future, the vision extends beyond semi-autonomous solutions. The ongoing development of vehicle diagnostic and prognostic systems, coupled with the continuous refinement of advanced positioning technology, provides the capabilities necessary for fully autonomous vehicles, creating exciting opportunities for heavy machinery and trucks to navigate without drivers.

What Is Autonomy?

The levels of autonomy in vehicles, as defined by the Society of Automotive Engineers, range from Level 0, where there is no driving automation and the driver performs all tasks, to Level 5, where the vehicle can handle all driving tasks in any environment without human input. Level 3 involves conditional driving automation, which means the vehicle can perform all aspects of driving in some situations, but the driver must be ready to take over when requested by the system.

In construction machinery, solutions in use today involve machine control for grading and digging, along with real-time comparison of as-built conditions to the original plan. The dozer's plan is pre-loaded, guiding the blade's movements while operators monitor the blade's activities on a video screen. Deviations between the plan and as-built conditions are transmitted to a control center for real-time decision-making, improving efficiency, reducing errors, and ensuring a more seamless construction process.

In long-haul trucking, advanced driver assistance systems (ADAS) are prevalent, including speed control and route planning. Adaptive cruise control is a common feature, allowing the vehicle to adjust its speed to maintain a set distance from the vehicle ahead, while improved route planning enhances fuel efficiency and reduces hours on the road. These technologies serve as assistant mechanisms with an operator in the loop, placing autonomous options at approximately Level 3.

The landscape of worldwide autonomy legislation is currently marked by a lack of universal standards regarding human-vehicle interactions, with the United States adopting state-specific regulations. Each use case must adhere to distinct regulations, shaped by factors such as proximity to people, other vehicles and the potential risks of injury or damage. Currently, the industry is navigating the challenges and opportunities presented by Level 3 autonomy, with the ultimate goal of achieving higher levels of automation in the future.

Growing Demand for Autonomy

The trucking and construction industries are ideal candidates for autonomous solutions, given the challenges they currently face. In the trucking sector, the demand for long-haul truckers has outstripped supply, with the American Trucking Association

estimating a shortage of 80,000 drivers in 2021 and growing to 160,000 by 2030, a trend exacerbated by increased demand for freight services and lack of interest in younger demographic groups. Similarly, the construction industry grapples with a shortage of skilled labor, prompting a shift towards autonomy to address workforce scarcity. By automating driving tasks, semi-skilled labor can focus on specialized activities, thereby optimizing workflows and improving productivity.

The motivation for autonomy in both industries is fueled by the difficulty in hiring skilled labor; however, the benefits extend beyond staffing. Adopting autonomous solutions increases the potential for significant efficiency gains and cost savings. Machinery is subjected to reduced wear and tear by optimizing routes and movements, thereby extending the lifespan of equipment and promoting operational efficiency. Activity is not interrupted by driver shift changes and machines can run nearly non-stop. A Boston Consulting Group (BCG) report suggests that implementing autonomous solutions in long-haul trucking could result in more than 30% savings in total ownership costs, over double the uptime per vehicle, and a 10–15% reduction in fuel consumption and emissions.

Safety on both highways and construction sites is enhanced with precise navigation that ensures constant awareness of a vehicle's location and destination, providing accurate navigation capabilities to minimize the risk of accidents and collisions. In addition, the data generated by autonomous solutions supports workflow optimization by offering valuable insights into key logistical factors, such as predicting the time of a truck's arrival at a warehouse or estimating the time it takes to dig a ditch or pave a highway.

The current state of automation in these industries is evident in the implementation of geospatial technology such as ADAS and task automation features in construction. These technologies leverage GNSS, inertial systems and other sensors to enhance operator productivity. As these new tools are investigated, safety takes center stage, with Automotive Safety Integrity Level (ASIL) certification serving as a crucial benchmark. The convergence of geospatial technology and autonomy not only addresses industry challenges but also promises substantial economic and environmental benefits.

Trimble Positioning Ecosystem

No single technology can provide the means to achieve full automation, due to the complexity of the natural environment.

Trimble's comprehensive positioning ecosystem, designed for original equipment manufacturers (OEMs) and Tier I manufacturers, encompasses various hardware and software solutions that work together to deliver the best possible results.

Over the years, Trimble has continued to improve its precise positioning engines for added safety and utility. Ideally suited for trucking, ASIL-rated Trimble RTX correction services ensure precise point positioning in real-time utilizing detailed LiDAR camera maps for navigation. Map-based localization (MBL) technology from Trimble further assists navigation, providing reliable and repeatable absolute positioning. The MBL process generates customized maps through a positioning and orientation system with post-processing software.

The ecosystem also includes GNSS and inertial reference systems, critical for testing autonomous solutions under real-world conditions. Additionally, it offers varying levels of immunity against multipath and extended outages, together with a combination of ground truth, testing and validation

systems, which are key to the development process.

Trimble ProPoint Go™ is an on-vehicle GNSS/inertial precise positioning engine that fuses GNSS observations, globally accessible high-accuracy correction services and measurement data from a variety of sensors (e.g., Inertial Measurement Unit (IMU) and vehicle odometry). Embedded in the computing platform of the vehicle, the system can achieve performance down to approximately 10 cm, aiding auto-steer and guidance on OEM vehicles.

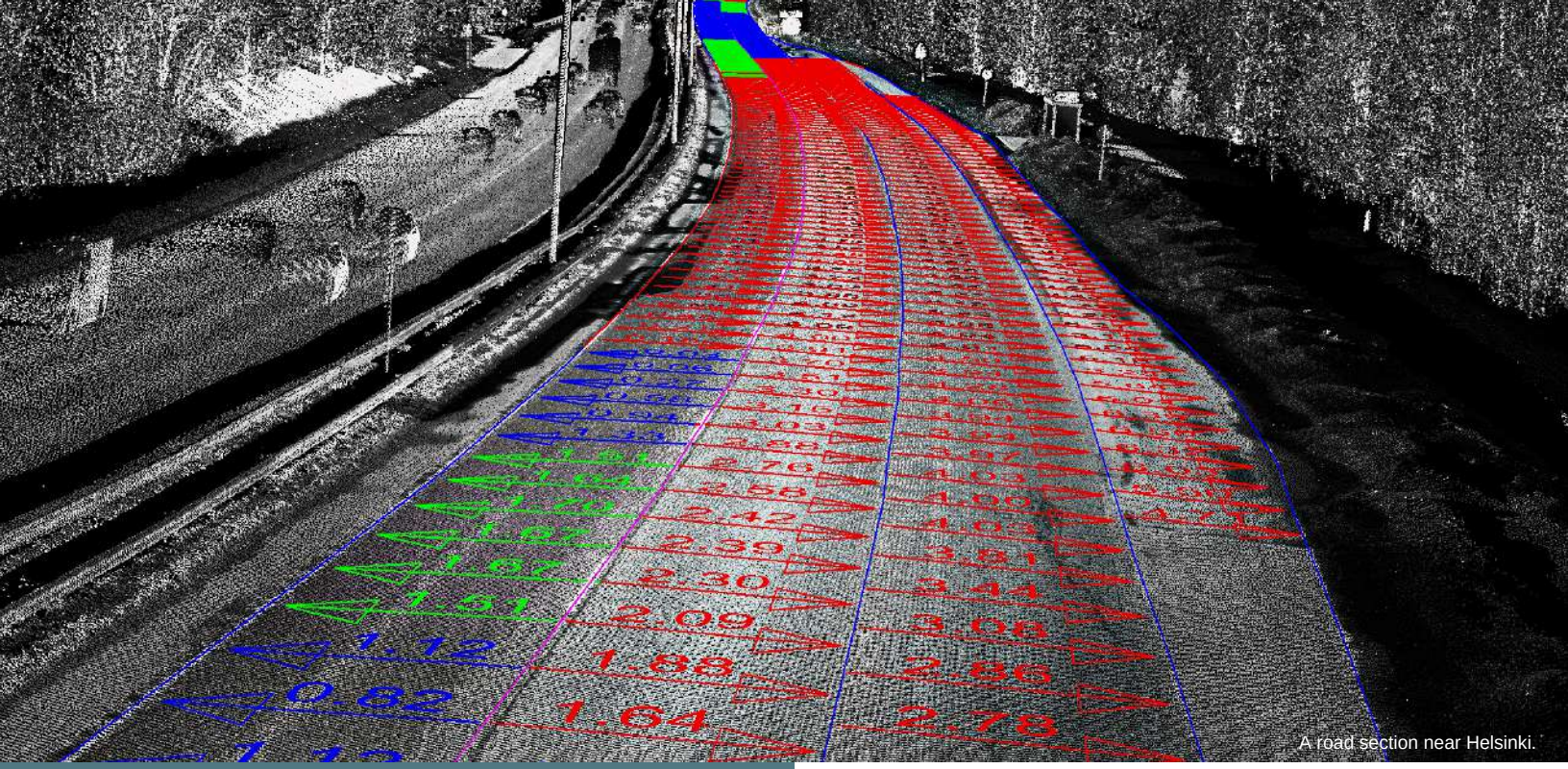
For fully autonomous scenarios, a comprehensive sensor data chain involving cameras, radar and LiDAR creates a real-time 3D virtual reconstruction. This reconstruction can be stored on the vehicle or transmitted via Wi-Fi to an operator/supervisor. Trimble collaborates closely with OEMs, employing two-way communication to support rapid prototyping and testing. This collaboration involves understanding the needs of the OEMs, refining requirements, and ensuring the development of bespoke solutions aligned with short, medium and long-term objectives.

Incremental Progress Towards Autonomy

A phased evolution is underway, encompassing personnel monitoring on vehicles, both onboard and remote, and progressing towards fully driverless systems. Central to this transition is the concept of workflow optimization, leading to a future where efficiency and seamless operations drive autonomous technologies. The integration of numerous sensors generating useful data not only enhances safety but also offers potential for additional business benefits.

However, it's important to note that certain challenges persist. Although Trimble's advanced positioning technology is ASIL certified, the critical neural networks that recognize diverse objects, e.g., squirrels, people and bicycles, remain uncertified in terms of safety. This highlights the ongoing need for rigorous testing and certification processes to ensure the reliability and safety of autonomous systems.

In this complex landscape, individual components are interacting within a larger autonomous ecosystem. A variety of machines and vehicles collaborate and work in concert to optimize business-level goals, as demonstrated by a compactor in a road paving workgroup or a truck navigating a busy intersection. As autonomy continues to evolve, the journey towards standardized regulations, enhanced safety protocols and the seamless integration of autonomous technologies into broader business frameworks remains a dynamic process.



A road section near Helsinki.

High-Precision Mobile Mapping for Accurate Road Surface Condition Parameters

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Is it possible to produce road surface condition parameters using LiDAR data? The simple answer is yes, but first, there must be an understanding of what LiDAR is. LiDAR technologies consist of active sensors that use electromagnetic waves in optical and infrared frequencies. There are several different types of imaging technologies within the wide concept of LiDAR. In this article, we focus on *RIEGL*'s Ultimate LiDAR™ technology, which was used to produce road surface condition parameters passing the official VTI (The Swedish National Road and Transport Research Institute) tests conducted in Sweden. Not all of the current commercial mobile LiDAR systems produce data that is accurate enough for the task that is described in this article. It has been shown that *RIEGL* VMX mobile laser scanning technology can be used in network-level road surface condition surveys at high speeds.

Motivation of This Work and How It All Started

Nordic Geo Center Ltd in Finland has developed a method to use the *RIEGL* VMX mobile mapping systems in accurate road measurements to replace the total station measurements since 2013. The background for this work is the previous experience of the key personnel in developing software and hardware for road surveys starting in the 1980s. Road surveys have been based on profiles and cross-sections for several centuries in the past due to measurement technologies, but the new data types open up new possibilities for the use of the data. Using LiDAR, the traditional method of measuring longitudinal and latitudinal sections is not needed anymore.

RIEGL Laser Measurement Systems released its first two scanner “crossfire” mobile laser scanning (MLS) system *RIEGL* VMX-250 in 2009. This instrument was presented in Finland already in 2010 and the demonstration convinced Hannu Heinonen, the founder of Nordic Geo Center Ltd, that MLS seemed to be ready for accurate surveying results from the perspective of land surveying.

Development from 2013 - 2023

The development started in 2013 with the *RIEGL* VMX-450 MLS system that was placed on a BMW X5 SUV vehicle. The typical vans of that time used as survey vehicles were deemed too clumsy for on- and off-road surveys and the BMW engine and gearbox technology was assumed to produce less interference for the system’s inertial measurement unit (IMU). It is also easier to produce the required driving dynamics for the proper use of the IMU, even though today many mobile laser scanner users want to acquire the data at constant speeds.

During the years, several *RIEGL* VMX systems have been used in the development. First the VMX-450, then VMX-1HA and VMX-2HA. The latest *RIEGL* VMX-2HA is operated by Nordic Geo Center Ltd since the summer of 2023.

Components of the VMX-2HA high-performance mobile mapping system, see figure 1:

- **two *RIEGL* VUX-1HA profile scanners** based on time-of-flight technology, each with a 1.8 MHz pulse repetition rate and 250 scan lines per second. These laser scanners have multi-target capability which for example enables the penetration of vegetation. The *RIEGL* waveform attributes provide much more information than just a range reading, such as calibrated amplitudes, a range-independent reflectance as well and a pulse shape deviation related to each measured point
- **a high-grade Inertial Navigation System (INS)** based on multi-band GNSS and a fiber-optic-gyro IMU which provides drift stability in challenging GNSS conditions
- **an optional camera system** which can be equipped with up to 240 MP resolution comprising up to 7 x 24 MP directional cameras and an up to 72 MP spherical camera
- **a central trigger & and time stamping unit** that ensures synchronization of all system components (INS, scanners, cameras, external devices) as well as the data transfer with up to 11 Gigabit bandwidths to the control unit. The control unit is a compact trolley-sized portable case that can easily be put in the trunk or the backseat of the car. It precisely controls the management of power, data acquisition, and operation of the laser scanners, INS/GNSS system, and optional cameras
- **the VMX-2HA roof mount** which enables a convenient mounting on commercially available Thule roof bars

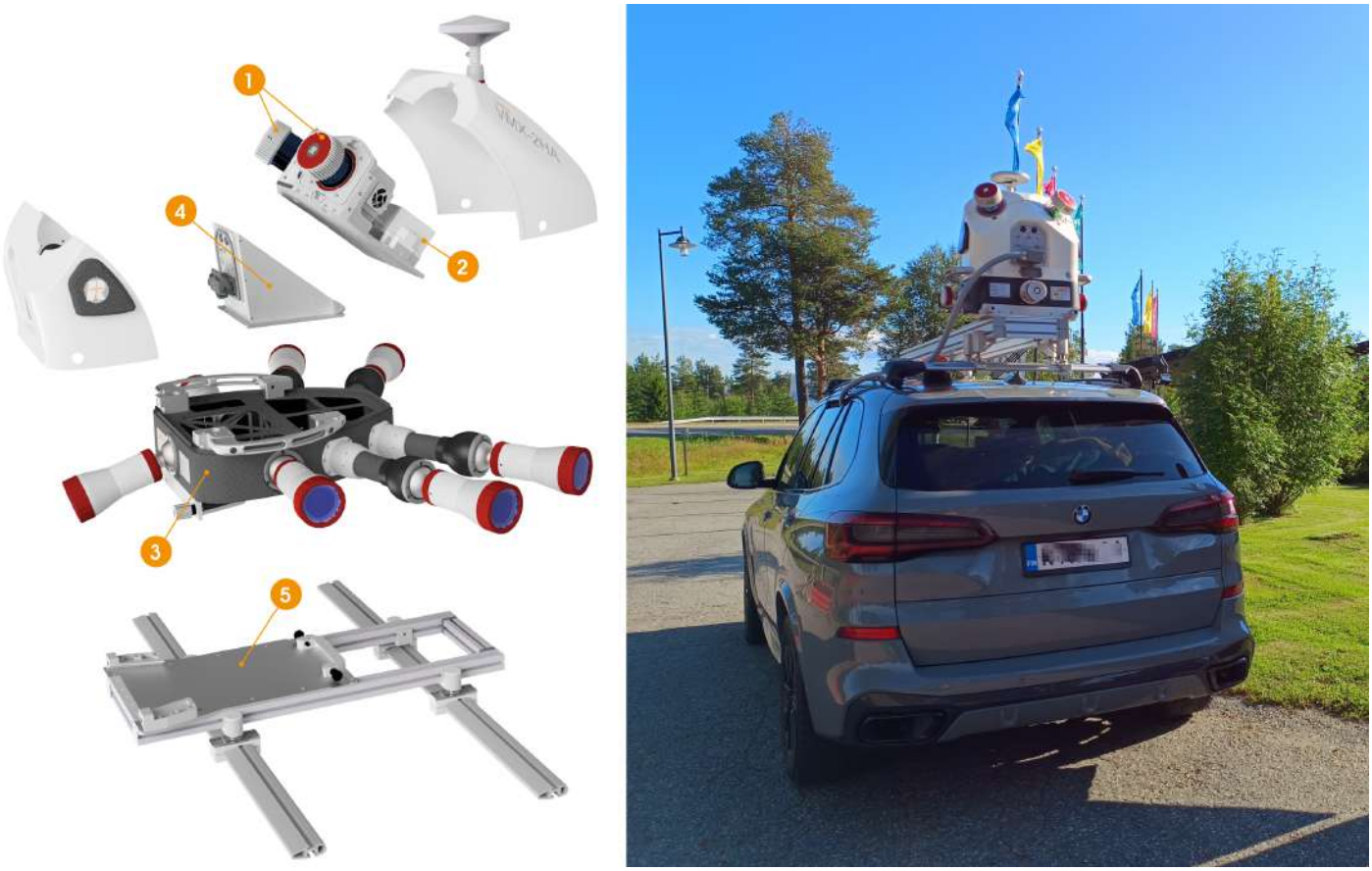

Figure 1: On the left an exploded view of the *RIEGL* VMX system and on the right the system attached to the surveying vehicle.

The BMW X5 has remained the surveying vehicle as the results have been good and every new vehicle type needs to be tested for suitability. Hannu Heinonen at Nordic Geo Center Ltd considers the vehicle as the equivalent to the tripod used in total stations and thus part of the measurement system. When aiming for the highest accuracies, all parts of the measurement system including the people using it, the ambient environment, weather, etc. start to add up to the total uncertainty.

Contrary to many guidelines, they use as few as possible survey tie points in the processing. The data is not good enough if tie points are needed every 50 - 500 meters just to connect the parallel records or match as it is generally called. Control points to check the accuracy of the data are another matter and there can be as many as the procurer wants to provide. In engineering-level surveys with *RIEGL* VMX, height control points are needed every few (3…6 km) kilometers and there is also a need for control points in GNSS-limited locations such as within forests or urban canyons.

According to the philosophy of Tauno Suominen and Hannu Heinonen from Nordic Geo Center Ltd, the human-intense acquisition of tie points/control points is expensive, so the value of MLS must be provided by diminishing the need for additional human resources. A second note on the control points is that they must be part of a reliable geodetic network measured with GNSS base stations and total stations. The heights should be leveled if possible. It is of no use to worsen a geometrically accurate point cloud by controlling it with RTK-GNSS survey points.

From Engineering Road Survey Projects to Road Surface Condition Surveys

The question at Nordic Geo Center Ltd has always been what else can be done with this quality of data and one direction led to road surface condition parameters. Would their data be good enough? The initial hypothesis based on their knowledge was positive, so they started to look into how to calculate the results from their data which is very different than the traditional data created by parallel highly accurate point lasers that provide sub-millimeter accuracy in distance measurement. As the results mean nothing without control to current standards, they took part in a couple of development projects by the Finnish Transport Agency (nowadays Finnish Transport Infrastructure Agency). The first results encouraged them to develop further until in 2019, when they were asked to participate in the VTI tests in Sweden. The VTI tests are arranged for the winners of the public tenders to check that their measurement systems provide data according to the standards.

In the 2022 VTI tests, Nordic Geo Center Ltd successfully produced all the parameters required for the systems used on Finnish roads. This time there were four about 1 km test sections in Sweden and one around 300 km test section in Finland.

Figure 2: *RIEGL* VMX measurement principle: The image illustrates the “crossfire” scan lines of the two scanners (colored in red and green). The foreground shows the VMX point cloud colored with the reflectance attribute, the background shows the optional RGB colored point cloud.

"At first, we did not produce all the required parameters, but we did pass the five about 1 km short sections which were needed to be repeated five times each at different speed. We also passed one of the more than 120 km loops which needed to be repeated twice. Due to rain, we could not acquire all the length of the second loop. As the VTI reference is well documented and measured, the results showed that we are on a right path."

Hannu Heinonen

At first, no one could believe that *RIEGL* VUX scanners could produce anything similar compared to these sub-millimeter lasers used for many decades. These lasers are also located very close to the road surface in front of the vehicle whereas the *RIEGL* VMX lasers do not meet the road surface perpendicularly but in a sloped angle. The profiles they produce are not perpendicular to the direction of the road either.

What Can We Produce With *RIEGL* VMX Systems?

Road surface condition parameters

A key product based on VMX mobile mapping data is road surface condition parameters. At the 2022 VTI tests, Nordic Geo Center Ltd successfully produced the following road surface profile parameters: IRI right, IRI left, Rut depth max, Rut depth right, Rut depth left, Height of Ridge, Position XYZ (SWEREF99 TM), Position Z (RH 2000) Crossfall, Hilliness and Transverse profile.

Table 1 shows the requirements and the acceptance interval for the Finnish vehicles in the 2022 test. (Source: VTI[1]). The longitudinal profile is based on the standard SFS EN 13036-5, the date and time of the measurement needs to be saved in the data according to ISO 8601 standard, the transverse profile needs to be filtered as instructed in the draft prEN 13036-8 for a standard or in a similar fashion and the IRI is calculated using the SFS EN 13036-5 standard. All of the above-mentioned standards are based on their international counterparts.

To check the results, it is also relevant to measure the reference measurements carefully and the references should be more accurate than the tested measurement systems. In Sweden, the reference values for transverse profiles were measured with the VTI-XPS which consists of seven LMI Gocator 2375, a GPS receiver and inertial navigation unit (OXTS Survey +). The values are measured for the width of 3.6 m and filtered for the width of 3.2 m. The profile is collected at every 0.1 m with one value every 1 mm in transverse direction. The transverse profile is used to calculate values for the rut depth, ridge and crossfall variables.

The longitudinal profiles were measured using a total station every 10 meters and the Primal, which will collect the values every 4 mm between the total station points while moving. The IRI values are calculated using these profiles. For curvature and hilliness, a XYZ position is measured every 4 and 10 m along the road. The radius is calculated for every three points along the section and the longitudinal slope is calculated every 2 m and 4 m points.

The position will be calculated with a combination of GPS and total station measurements. Only the first 100 m of the test sections are used for reference to minimize the length differences between different systems.

Parameter	Category	Acceptance interval	Limit
IRI Right	Reference ≤ 2.00 mm/m	Ref-0.35 mm/m ≤ TV ≤ Ref + 0.35 mm/m	72%
IRI Right	Reference ≤ 2.00 mm/m	Ref-(0.35 + (Ref-2.00) x 10%) mm/m ≤ TV ≤ Ref + (0.35+(Ref-2.00)*10%) mm/m	68%
Rut depth max	Reference ≤ 7.5 mm	Ref-1.0 mm ≤ TV ≤ Ref. + 1.0 mm	77%
Rut depth max	Reference ≤ 7.5 mm	Ref-(1.0 + (Ref-7.5) x 5%) mm ≤ TV ≤ Ref + (1.0+(Ref-7.5) x 5%	77%
Rut depth left	Reference ≤ 7.5 mm	Ref-1.0 mm ≤ TV ≤ Ref + 1.0 mm	77%
Rut depth left	Reference ≤ 7.5 mm	Ref-(1.0+(Ref-7.5) x 5%) mm ≤ TV ≤ Ref + (1.0+(Ref-7.5) x 5% mm	77%
Rut depth right	Reference ≤ 7.5 mm	Ref-1.0 mm ≤ TV ≤ Ref + 1.0 mm	72%
Rut depth right	Reference ≤ 7.5 mm	Ref-(1.0+(Ref-7.5) x 5%) mm ≤ TV ≤ Ref+(1.0 + (Ref-7.5) x 5%) mm	72%
Height of ridge	Reference ≤ 7.5 mm	Ref-1.0 mm ≤ TV ≤ Ref + 1.00 mm	77%
Height of ridge	Reference ≤ 7.5 mm	Ref-(1.0+(Ref-7.5) x 5%) mm ≤ TV ≤ Ref+(1.0+(Ref-7.5) x 5% mm	77%
Position X,Y SWEREF99		|TV-Ref| ≤ 0.75 m	95%
Position Z RH 2000		|TV-Ref| ≤ 4 m	95%
Crossfall regression	|Reference| < 3.00%	|TV-Ref| ≤ 0.50%	85%
Crossfall regression	|Reference| ≥ 3.00%	|TV-Ref| ≤ 0.50% + (|Ref|-3.0) x 5%) %	85%
Curvature	|Reference| < 10.0 1/m	|TV-Ref| ≤ 5.0 1/m	85%
Curvature	|Reference| ≥ 10.0 1/m	|TV-Ref| ≤ 5,0+(|Ref|-10,0) x 10%) 1/m	85%
Hilliness	|Reference| < 3.00%	|TV-Ref| ≤ 0.75 %	85%
Hilliness	|Reference| ≥ 3.00%	|TV-Ref| ≤ 0.75 + (|Ref|-3.0) x 5%) %	85%
Transverse profile		Point by point |TV-Ref| ≤ 0.5 mm	80%

Table 1: Acceptance limits for validity at the test sections.

Abbreviations and explanations:

- *TV (abbreviation for Tested Vehicle); this is the value that the participants provide from their systems.*
- *Ref is VTI reference value.*
- *The percentage limit means that e.g., 72% or more of the values you have provided should be with the acceptance interval. Your IRI does not pass if only 71% of the IRI values are within this limit.*
- *Position Z means the height given in the Swedish geodetic height system RH2000.*
- *Position XY is also given the Swedish system which in turn is based on the European reference ETRF frame.*

These parameters needed to be calculated from the data acquired five times at two different speeds, 40 km/h and 70 km/h in four 1 km test sections and two times in a longer, around 300 km section. The data for the latter long section was acquired in two consecutive runs during the same day, so the results also show if the time and temperature-dependent errors in the scanning system are kept well under control. The data for the longer section was acquired at normal traffic speeds varying between 40 – 80 km/h and checked for repeatability and reproducibility. Speed dependency means that the maximum absolute value of the difference between the average value of all measurements at different speeds is calculated and should remain within the specified limits.

The processing of the *RIEGL* VMX-2HA data to produce road surface condition parameters is a semiautomatic process that starts with the calculation of the trajectory geometry. Once the trajectory quality meets the requirements of the project, the rest of the point cloud processing is a largely automatic process in *RIEGL*'s RiPROCESS software. If necessary, the different runs can be matched together, but this is not always required. It should be noted that due to the nature of network-level road condition surveys, sometimes thousands of kilometers are surveyed and results need to be provided in a very short time period, the use of signal/control points is not possible in terms of time. Many LiDAR systems seem to need signal points to achieve the required level of accuracy or even just to combine different data sets. In this test, the positional accuracy requirement is ± 0,5 m for both X and Y and ± 2m for Z value. Note, that the position needs to be within limits also in forested areas where trees are on both sides of the road. More than 50% of the roads in Finland are in forested areas and many of them are narrow as well which means that the positioning of any used surveying system needs to be good.

Compared to the traditional, profilometer-based road survey methods, LiDAR is easier to acquire, because the vehicle does not need to be kept in a specific location on the lane. As an active sensor - LASER - is used, mobile laser scanning is also inherently independent of the ambient light and hence, to improve productivity, data acquisition can be done day and night. Ambient light is only required if images are to be taken simultaneously.

The traditional road surface measurement technology seems to achieve repeatability by driving the acquisition runs in a specific part of the road in relation to the painted lines. The technology has also problems with the length of the roads, which is why the test teams calibrate their vehicles on designated road sections during the tests in Sweden. During the contract period, the acquisition vehicles are also regularly cross-checked for data consistency. Therefore, it is also worth noting that the *RIEGL* VMX systems are factory calibrated and do not need to be calibrated at any point during the field acquisition. The solidly build structure is very stable and designed for work in industrial production. In particular, the geometry and position data are several orders of magnitude better than with typically used traditional mobile road survey methods.

Engineering surveys

However, the *RIEGL* VMX system's main task is to create geometrically accurate data when properly used. The excellent data quality is the base for all types of engineering surveys such as road design, controlling and monitoring as-build infrastructures such as bridges, tunnels, and drainage. There are software tools that allow to calculation of the road geometry that represents the current state of the road. This kind of best-fit road geometry as well as the other parameters also allow one to check the state of the road in an accident investigation. In particular, older, heavily trafficked roads might be already structurally damaged in such a way that a repair or lower speed is necessary.

Harald Teufelsbauer, MLS Business Division Manager at *RIEGL* Laser Measurement Systems, puts the spotlight on the versatility of the VMX Laser Scanning System and the increase in efficiency and productivity for the users. "On the one hand our mobile mapping systems provide the precision to deliver road profile parameters, as e.g., proven by VTI acceptance tests. On the other hand – with the same equipment, during the same mission, and without spending

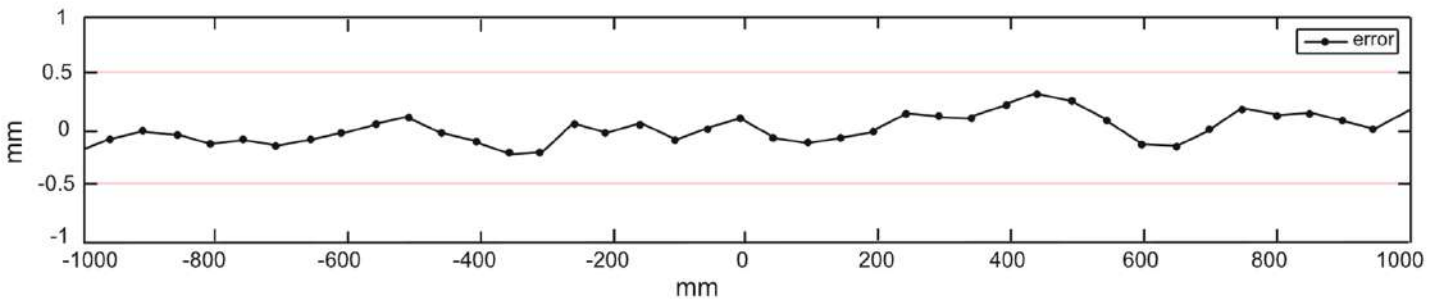

Figure 3: An example of the transversal profile difference between the VTI reference value and the value created with the *RIEGL* VMX. The difference is marked as an error and the vertical scalebar shows the difference in millimeters.

any additional time in the field – the user will get so much more information out of the system, whereas traditional methods need the acquisition with different systems in multiple mission in order to achieve the goals. The benefit of *RIEGL* Mobile Mapping is the accurate mapping of the complete 360 degrees clearance profile along the travelled path. That allows to capture in a single run not only the lane travelled, but also the surrounding environment along the travelled path. Since the visibility of some objects of interest might be obstructed by any obstacles such as traffic, multiple

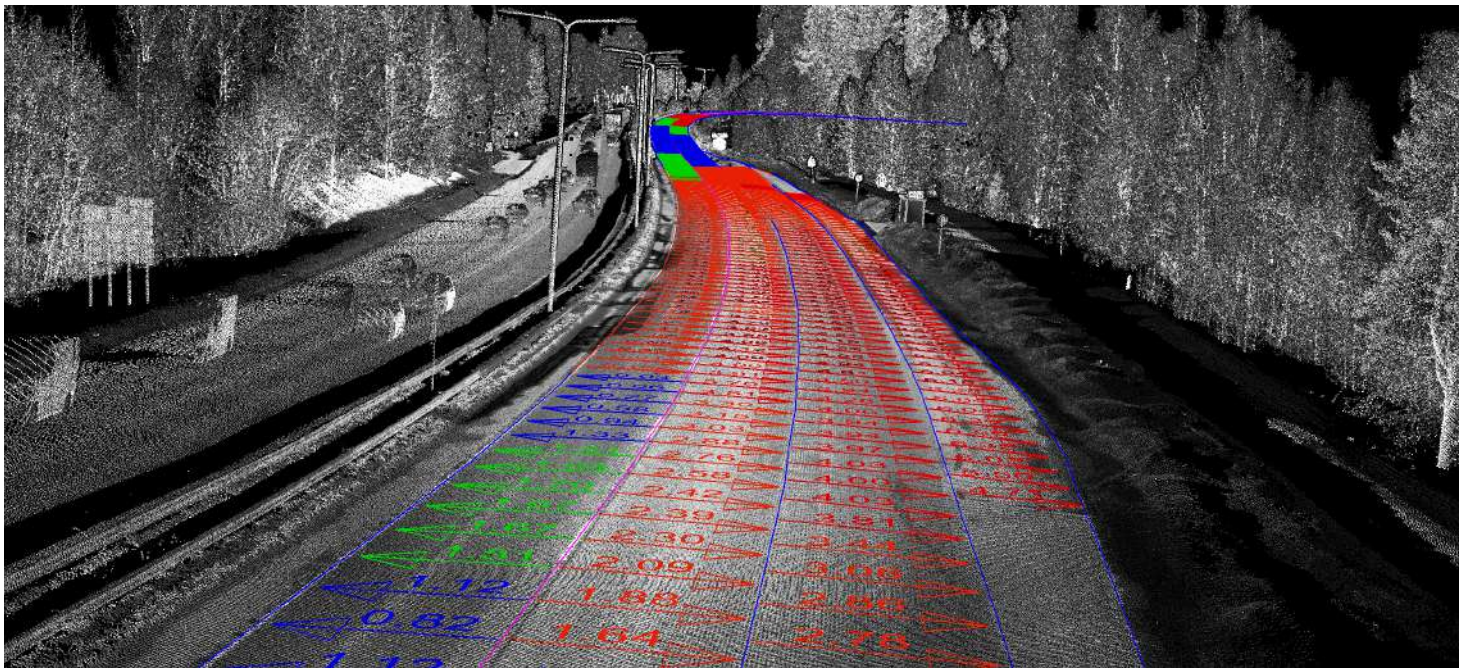

Figure 4: A road section near Helsinki, where the structure of the road has clearly failed. The arrows show the direction of the crossfall in each lane and for visualization purposes all the values sloping from left to right are painted red illustrating the wrong sloping direction in a curve.

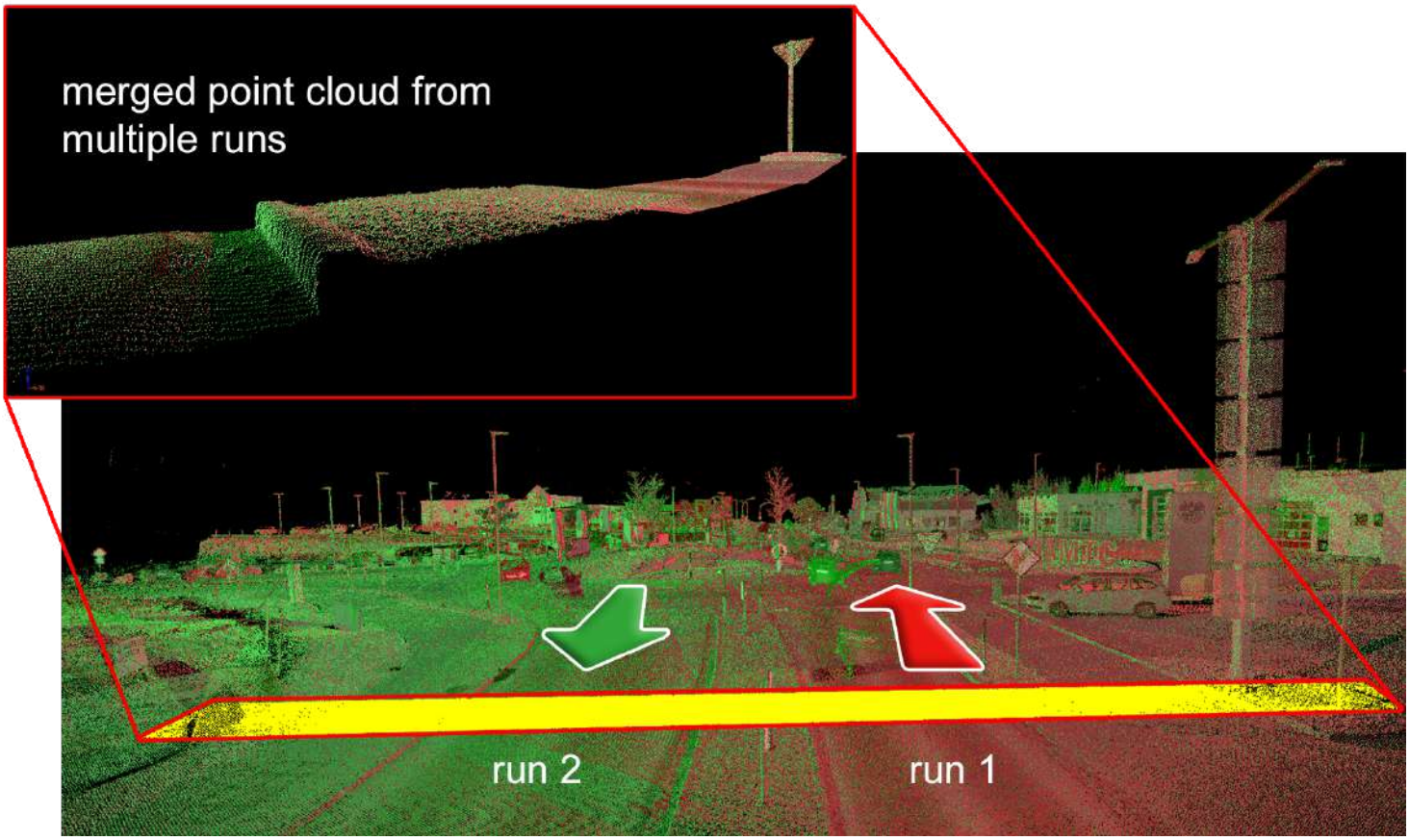

Figure 5: The point cloud shows the results of *RIEGL* rigorous scan data adjustment, resulting in a precisely aligned point cloud acquired by two runs driving in opposite directions (run 1 colored in red; run 2 colored in green).

runs on different lanes or in different directions are common practice in mobile mapping. Due to a highly accurate geo-referencing of each individual scan pass as well as a rigorous scan data adjustment of overlapping scan data captured from multiple runs, the result is a consistent point cloud with a feature rich 3D representation of the complete transportation infrastructure as well as the surrounding topography."

In addition to high accuracy surveys, the same VMX data can be used for example to model and check road furniture, document bridges in high accuracy, monitor deformation of rock cuttings and slopes along the road (see figure 6), conduct a vegetation analysis and passage analysis for oversize vehicles, but is also widely used to produce high-definition maps for autonomous vehicles. The digital elevation model of the surrounding area next to the road, in combination with the precise information of crossfall, rutting, potholes and other road defects allow a very precise modeling of water runoff, drainage or aquaplaning risk in the case of heavy rain.

Future Plans

One of Nordic Geo Center's future goals is it to check which other road surface condition parameters can be extracted from the VMX data. It is clear that the calibrated reflectance values could be used to check the reflectivity of the road signs and paintings. Furthermore, the shape, area, and volume can also be calculated from the data and the ruts with steep edges can be classified as more dangerous than the ruts with gently sloping edges.

It is also of interest to use this type of data for the road resurfacing workflow as minor geometric issues can be fixed during resurfacing. Similar in concept to railways, where the rails and minor rail geometry issues are corrected at the same time when repairing the track. When the geometry problem is too large, the tamping machines can no longer fix it. Currently in Finland the resurfacing vehicles on the road are often guided using a total station. Nordic Geo Center's approach would be to survey the road surface in order to generate a 3D model first and then it will be possible to attain the height position of the machine-controlled vehicles from the model. The accuracy of the GNSS is then sufficient for the XY positioning of the resurfacing vehicle. The process of milling and resurfacing will become much more simple and more accurate than the current total station-based machine control.

The new 3D laser mapping technology provides new kind of raw data which can be used to create new types of products, 3D visualizations, reference data for road design, or, for example, it can be used to create a best fit road geometry. These products could be used directly instead of processing the data into old output formats such as excel spreadsheets. The development of measurement tools and methods is only part of the overall process, where the use of data as part of the overall process also needs to be inspected in a new way.

[1] Source: VTI Test Description – 20022-09-01. Quality requirements and approval procedures Procurement of Road Condition Measurements in Finland, Thomas Lundberg, Diarienummer: 2019/0076-9.1.

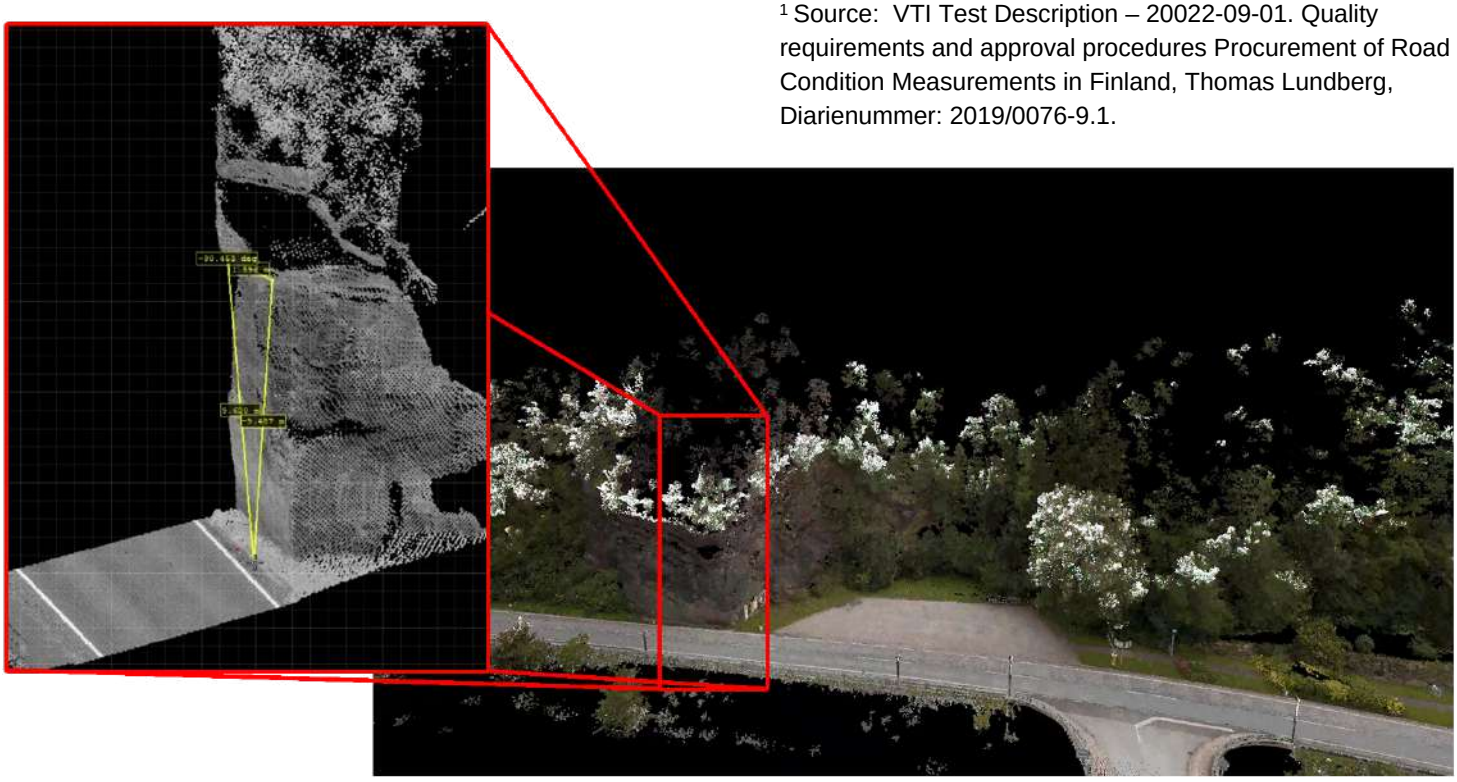

Figure 6: *RIEGL* Mobile Mapping point cloud data: High resolution coverage of the road infrastructure as well as the surrounding terrain. The zoomed area shows a rock formation close to the clearance profile of the road.

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up to 4 cameras including spherical camera	up to 4 cameras including spherical camera	up to 4 cameras including spherical camera	up to 9 cameras including spherical camera and up to 2 high-speed pavement cameras
		multiple swivel positions for improved scan pattern in multi-pass applications	simultaneous capturing of spherical and directional imagery with a total resolution of up to 1370 MP/sec
typ. point density 550 points/m² on pavement surface @ 80 km/h	*typ. point density 1,100 points/m² on pavement surface @ 80 km/h*	*typ. point density 3,200 points/m² on pavement surface @ 80 km/h*	*typ. point density 6,400 points/m² on pavement surface @ 80 km/h*

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Image Credit: Pix4D

Transforming Road Safety: Pix4D Solutions For Road Development And Collision Reconstruction

By The Pix4D Content Team
Content Marketing
Pix4D

New roads require new maps to track progress and follow strict laws. Aerial and terrestrial photogrammetry provide detailed insights into road conditions for safety and maintenance, saving time and making roads safer.

In the landscape of road development and safety, innovative technologies play a pivotal role and Pix4D, a leading provider of photogrammetry software and hardware, provides innovative and effective solutions. This article looks at the impact photogrammetry and technology can have on road safety, first with the use of drones in India, and then the benefits of terrestrial technology for road safety through the PIX4Dcatch RTK workflow. This article showcases the unique applications of both aerial and terrestrial mapping for road safety.

Road Safety in India

India, now the world's most populous country, is rapidly expanding its road networks. Current regulations for road infrastructure projects require developers to submit orthomosaics, digital surface models (DSM), digital terrain models (DTM), and volumetric analysis. This is to ensure the quality of new roads across the country and improve regulations and record-keeping.

However, this can require extensive surveying for road builders. As a result, drone mapping is now being used to provide data for infrastructure surveys. Using aerial imagery to create maps for road surveys can be implemented to build new roads or carry out maintenance without stopping traffic.

Benefits of Drone Mapping For Road Safety

Skytek Drones is a drone service provider based out of Hyderabad. The company began in 2022, and since then has been working on projects in infrastructure, real estate, and mining. The team is made up of surveyors and geologists who use drones to capture and process photogrammetry data. Skytek Drones was recently asked to survey an area before road development to ensure all necessary data was available for the authorities. This would ensure the project team was complying with the latest regulations as well as help record the state of the land being developed.

India is rapidly expanding its drone services across the country thanks to government-backed initiatives to map terrain with drones. As a result, companies like Skytek Drones can benefit from wider awareness of drone technology and its capabilities.

The benefits of generating DTMs, contour lines, and extensive stockpile analysis are that they help constructors keep track of material movement and follow compliance requirements. Generating them can quickly be done with aerial mapping using accurate photogrammetry software; in this case, Skytek Drones used PIX4Dmatic and PIX4Dsurvey.

Drone Mapping for Road Development

PIX4Dmatic, launched in 2020, is a high-powered desktop photogrammetry software that processes data captured with terrestrial scanning apps or aerial drone flights, notably faster than many alternatives on the market. PIX4Dmatic is tailored for large-scale mapping projects as well as corridor projects, which is ideal for bigger terrain surveys. The software also features built-in de-ghosting and sky-filtering options, allowing users to edit their outputs and refine the point cloud. Meanwhile, PIX4Dsurvey is a digital surveying tool that can convert point cloud data into CAD-ready files, as well as create measurements for volumes or contour lines.

The Skytek Drones team set out with a Mavic 3E RTK drone to gather data. Over the course of three flights, they gathered 3,880 images which were then imported to PIX4Dmatic.

Processing with PIX4Dmatic converted the images and geolocation data into an orthomosaic as well as a point cloud which was then exported into PIX4Dsurvey. With PIX4Dsurvey, Skytek Drones's team generated a DTM and measured the volume of stockpiles around the site. Finally, they mapped out the contours of the area, completing all of their results.

Figure 1: An aerial survey with drones includes contour data, with the lines here marked with black labels.

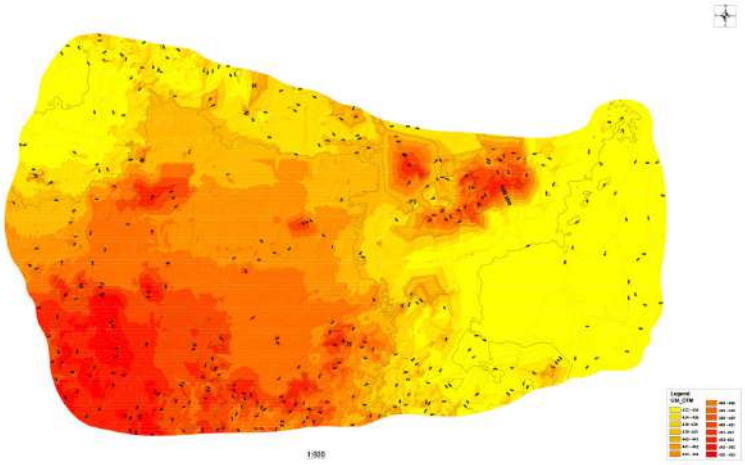


Figure 2: The digital terrain model (DTM) generated with Pix4D software shows the elevation changes across the project site.

Efficiency Meets Precision: A Drone Mapping Workflow with Pix4D

The drone mapping workflow with PIX4Dmatic and PIX4Dsurvey saved the Skytek Drone team days of work. The results were entirely compliant with the Indian government's regulations and were generated faster than the clients had ever seen before. Skytek's results were incredibly accurate, which also impressed the clients. With the drone surveys, the Skytek Drone team generated a GSD of 3.2 centimeters being represented per pixel which is a high level of detail.

Thanks to the government-mandated use of surveys, drone mapping is becoming more and more popular as a faster, more innovative surveying method. Skytek was able to demonstrate the benefits of photogrammetry with drones to their clients and save time with this technology. With this project in their portfolio, they can demonstrate their skills and services to new clients and expand their business reach.

Nani Rayavarapu, CEO of Skytek Drones, affirmed the success of Pix4D's solutions, stating, "Pix4D's results gave us the accuracy needed and saved us a lot of time in generating contour lines and measuring stockpile volumes. This process instilled confidence in our team to take on big projects and execute them with a quick turnaround time."

Collision Reconstruction and Photogrammetry

Pix4D's applications for road safety go beyond infrastructure development and offer significant benefits for collision reconstruction as well, especially through their terrestrial workflow, PIX4Dcatch RTK. Collision reconstruction is fundamental for road safety: analyzing the causes of accidents aids in understanding how similar incidents can be prevented in the future.

Collision reconstruction in the courtroom has evolved from hand-drawn sketches on blackboards to low-fidelity, basic animations, to high-quality video recreations that represent real-time accounts of an accident. These 3D collision reconstructions are used to show juries exactly what happened during a collision sequence. Recent advances in computer technology, including Pix4D software's evolution, allow experts to produce quality reconstructions that can be presented in the courtroom from multiple perspectives. This improves the jurors' understanding of the cause of a collision and helps them to reach a fair decision in legal proceedings.

The PIX4Dcatch RTK Workflow

The PIX4Dcatch RTK workflow provides sub-centimeter accuracy to terrestrial photogrammetry scans. This is achieved by attaching an RTK device to a smartphone or an iPad. When paired with iOS devices equipped with LiDAR sensors, the RTK device and PIX4Dcatch create a unique workflow combining LiDAR, GNSS, and photogrammetry. A unique feature of the PIX4Dcatch RTK workflow when used with PIX4Dmatic, is the ability to merge aerial and terrestrial data into a single accurate model. The aerial data is enriched by more detailed ground information, and areas that are obscured from the air can be filled in with a terrestrial perspective. This allows users to obtain the most comprehensive and accurate model for their scenes. For example, a forensic expert could record a car collision from both the air (capturing roads and the surrounding area) and the ground (capturing details on the crashed vehicles and evidence).

A Collision Reconstruction Professional Uses Pix4D

Dr. Lloyd, a professional specializing in collision reconstruction who adopted Pix4D's technology, expressed his excitement about the workflow's capabilities, stating, "Now, with PIX4Dcatch RTK I can create detailed 3D models with my mobile device and can also mark Ground Control Points (GCPs) to ensure the accuracy of my collision scene mapping projects using drones."

Figure 3: A digitized collision vehicle using PIX4Dcatch and the RTK device.

Recreating a Motorcycle Collision in 3D

For work that is going to be used in court, accuracy is paramount. Whether it is a helicopter accident or a multi-vehicle collision, these projects require a small ground sampling distance (GSD) which produces a highly accurate, detailed 3D map. This is because a small GSD includes more details, which in turn creates more automatic tie points in the reconstructions but can require longer processing times. In the past, Dr. Lloyd processed collision scenes with PIX4Dmapper, which could take up to 3 days to complete. However, with the advanced processing speeds of PIX4Dmatic, he cut his photogrammetry processing time on the highest settings down to just 12 hours.

Figure 4: A collision recreated in 3D and processed in PIX4Dmatic.

Once the data is processed, Dr. Lloyd does his post-processing editing. Off-ground points in the point cloud that had been generated by vehicles waiting at a nearby red light had to be deleted. He then used the de-ghosting filter in PIX4Dmatic to remove cars or their shadows from the orthomosaic tiles. In the past, this had to be done by manually editing the TIFF files in Photoshop, so the automated tool is a huge time saver.

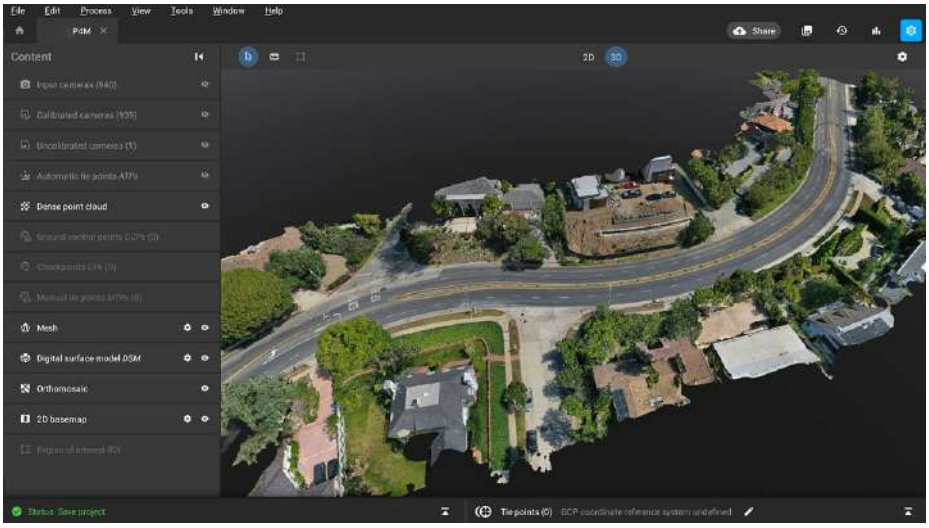


Figure 5: The collision scene was an urban area which Dr. Lloyd captured with a drone and added details with PIX4Dcatch and the RTK device.

Before using photogrammetry, Dr. Lloyd relied upon various methods to validate his scene reconstruction accuracy - including a roller wheel and a total station to measure the distance between reference points. With the RTK device, the GCPs were easily marked and accurate to less than a centimeter. As a result, the accuracy validation process for the 3D collision reconstructions has been streamlined and saves Dr. Lloyd time in the field. In addition, PIX4Dmatic makes it very easy to mark GCPs in the software thanks to its intuitive workflow.

This new workflow has made a huge difference to Dr. Lloyd's collision reconstruction projects. He used to split his time equally between processing a scene and collision analysis. With PIX4Dmatic, processing times have been reduced by 80%, meaning he can sometimes complete data collection and scene processing on the same day. collision reconstruction is a time-consuming process, but thanks to the PIX4Dcatch RTK workflow and PIX4Dmatic, saving time has not come at the expense of accuracy.

Shaping the Future of Road Safety with Photogrammetry and Pix4D

In India, Pix4D's drone mapping workflow has not only streamlined the surveying process for road development but has also set new standards for efficiency and accuracy.

The benefits extend beyond compliance, as demonstrated by the confidence instilled in Skytek Drones to undertake larger projects with rapid turnaround times. In accident reconstruction, utilizing the PIX4Dcatch RTK workflow has ushered in a new era of precision. The combination of RTK, LiDAR, and photogrammetry has resulted in an efficient and accurate workflow that has contributed to a deeper understanding of collision scenes. The advancements in speed, accuracy, and usability empower professionals like Dr. Lloyd to provide comprehensive insights into legal proceedings, ultimately contributing to public safety.

As Pix4D continues to innovate and evolve, its impact on road safety is poised to grow, promising a future where road development is efficient, precise, and, most importantly, safe. Pix4D's contribution to road safety with drone mapping for infrastructure projects and PIX4Dcatch RTK for accident reconstruction represents a significant leap forward in using technology for the greater good.

TOPODRONE LiDAR installed on a car for mobile mapping.

Mobile LiDAR Technologies For Advance Road Inspections

By Ilya Shikov
Co-founder & CTO
TOPODRONE

Sometimes it is impossible or impractical to perform a drone LiDAR survey due to the presence of no-fly zones (NFZ), a military or administration restriction on drone flight. Or it is simply unfeasible to perform drone surveys, for example, when it is necessary to create a corridor map of a narrow area, such as the street from "fence to fence" or to inventory the newly built road. At the same time the use of standard technologies like total stations or GPS takes quite a long time or requires special activities in the organization of workflow on the highway, involving special equipment and tools.

To fill the gap mobile laser scanning could be applied for road monitoring. Using a designated mounting, a LiDAR system can be installed on a car or a backpack. Additionally it can be equipped with a remote GNSS antenna, allowing it to receive the signal in the cramped conditions of city streets. At the same time the high-precision inertial module (IMU) provides the possibility of surveying even in case of short-term absence of GNSS signal when passing overpasses and tunnels. A few case studies below will demonstrate how surveyors globally practice road mapping and inspections with mobile LiDAR technologies.

Road Mapping In Bangladesh

This case study is based on the data collected during a project in Bangladesh, where drone flying is forbidden. The road with overpasses, tunnels, and rugged terrain was surveyed with TOPODRONE LiDAR HI-RES mounted on a car. The orientation of the laser scanner and the inclination of the sensor provided an accurate and detailed survey of

the roadbed. The section of about 3 km was scanned in two opposite directions with an average speed of 30 km per hour.

After performing a mobile laser scanning, at the end of the process, a highly accurate trajectory was calculated in the TOPODRONE Post Processing software, and a point cloud was generated. To analyze the quality of the trajectory the path of the car was studied as displayed with light green color highlighted areas with high accuracy (fixed), dark green with medium accuracy (fixed), and yellow color with low accuracy (float).

The next step was to generate a point cloud considering the LiDAR calibration angles in the national survey grid. At the final stage accuracy control was performed with the use of GCPs measured on the road markings and characteristic points of the terrain. Figure 3-6 shows samples of the three-dimensional model obtained by mobile laser scanning.

Also, they demonstrate a visual analysis of the planimetric accuracy and in Results of automated vectorization of poles and power lines.

Surveying City Roads in Spain

This case study highlights the project of mobile laser scanning in the city of Málaga, carried out by ATyges, the leader of the surveying market in Spain.

First of all, the EMLID REACH RS base station was installed on the roof of a building, which ensured excellent satellite signal reception and the safety of the equipment.

The TOPODRONE LiDAR system was then attached to the vehicle using an easy-to-installed MOBILE KIT mount, and mobile laser scanning was carried out at night when there was a minimum of cars and pedestrians on the roads.

To estimate the accuracy of the materials, Atyges specialists measured several control points, evenly distributed along the route. Once the fieldwork was completed, GNSS & IMU post-processing was performed in TOPODRONE Post Processing software to obtain a high-precision trajectory and LIDAR point cloud, taking into account the boresight angles automatically calculated by the software. The accuracy and convergence of the point cloud to the pre-measured GCPs was then estimated.

The results of the mobile scanning were accurate and detailed. TOPODRONE LiDAR system installed on top of the car provides 1-3 cm x,y,z accuracy without any enhancements and adjustments using GCPs. The entire data processing workflow was straightforward and did not require the use of different types of software. All the team needed was to install a base station, mount a LiDAR system on a car, drive carefully at a speed of 30 km/h and post-process the data in TOPODRONE software. As a result they got an accurate point cloud that can be easily converted into CAD layers and maps.

Figure 1: The path of driving, a test site in Bangladesh.

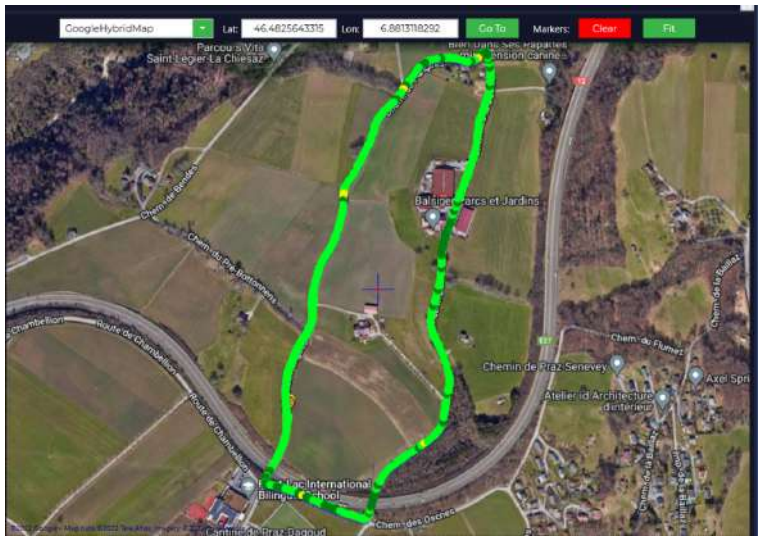


Figure 2: Results of trajectory post processing.

Figure 3: Generation of mobile laser scanning point cloud in real time.

Combining Airborne And Mobile Lidar Scanning: Choice Of US Surveyors

This case study shares the practices of US surveyors on how to apply the same LiDAR equipment both for a UAV and a car. Jack W. Berry & Associates, a leading aerial mapping and aerial Photography LIDAR service provider in Georgia and Southeast of the United States practiced the synchronization of drone-based LiDAR, Photogrammetry, and mobile laser scanning survey approach. They performed a mapping project in Peachtree City, GA. LiDAR datasets were captured by TOPODRONE LiDAR HI-RES while photogrammetry data was collected with the TOPODRONE P61 camera. Both devices were simultaneously installed onboard of DJI M300 drone. After finishing the flights the same TOPODRONE LIDAR HI-RES was installed on a vehicle to perform mobile laser scanning of the road and surrounding infrastructure.

Drone and mobile laser scanning datasets were automatically processed in TOPODRONE Post Processing software and required no additional actions to couple them together. As a result, a highly detailed point cloud with 1-3 cm x,y,z accuracy was generated which allows us to automatically trace and create CAD data of roads, borders, road signs, power poles, wires, buildings, trees terrain level, etc.

The survey results identified the following advantages of the method: the same LiDAR equipment can be used on different platforms providing an outstanding level of versatility, efficiency, and accuracy.

TOPODRONE would conclude that a mobile LiDAR survey is the easiest and fastest way to get accurate & and up-to-date geometric data and digital footprints of buildings. Finally, it can be noted that the installation of TOPODRONE LiDAR equipment on a vehicle significantly extends the use of laser scanners and allows meeting the challenges in places where there are flight restrictions, or it is not reasonable to carry out drone surveys.

The accuracy and detail of the mobile laser scanning data allow for creating 1:500 scale topographic plans, at the same time there is no need to perform instrumental surveys of sagging wires, curbs, road signs, etc. Special attention should be paid to the possibilities of automated classification of point clouds, highlighting of terrain relief, and vectorization of power lines, poles, fences, road markings, and road signs. All these advantages greatly simplify and speed up the process of mapping.

Figure 4: Mobile laser scanning point cloud.

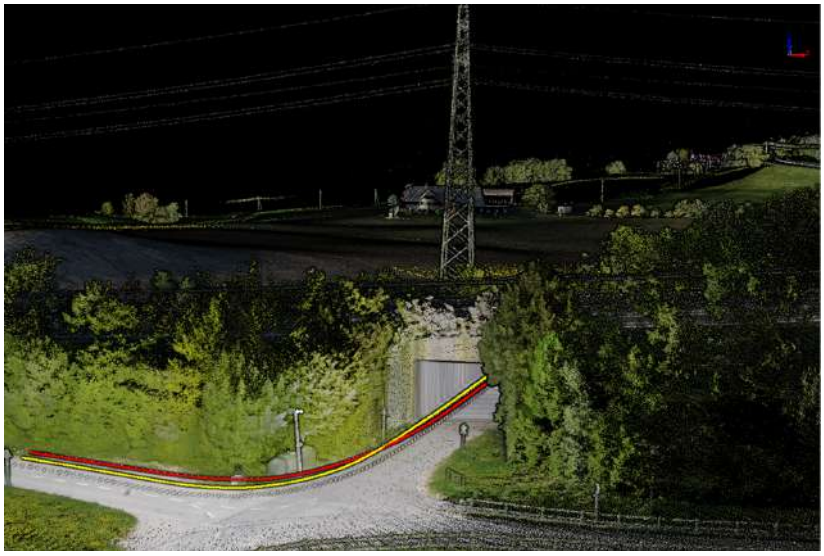


Figure 5: Mobile laser scanning point cloud.

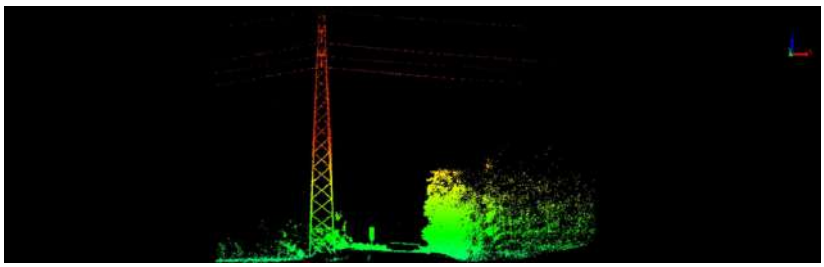
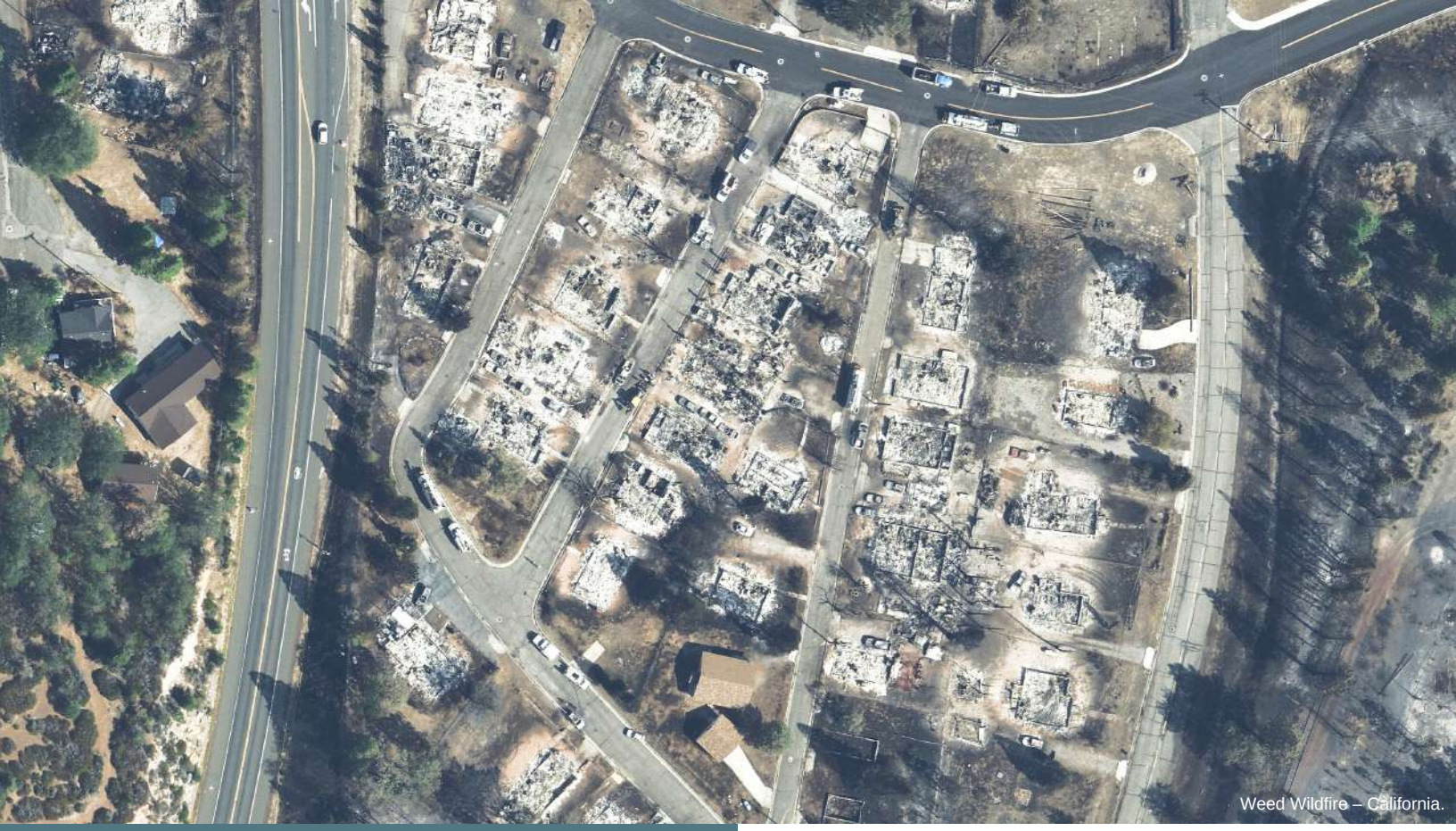


Figure 6: Mobile laser scanning point cloud.

Figure 7: UAV & mobile point cloud.



Weed Wildfire – California.

Geospatial Technologies for Climate Change Mitigation

By Angie Brewster
Marketing Manager - Content & Brand
Vexcel Imaging

Drought. Wildfires. Hurricanes. Tornadoes. The world's climate is becoming more severe, more erratic, and more dangerous. Geospatial technology can help map, analyze, and synthesize information to help address and better understand these global challenges.

There are pockets of danger zones that exist in multiple communities around the globe, pockets where weather patterns have put areas on high alert, areas like California where the wildfire risk has grown significantly over the last several years. In a new study by Nature[1], scientists used a machine-learning model to show that climate change increased the risk of fast-moving wildfires by about 25% on average. This data has not only put homeowners but insurers on high alert as they seek to get information on properties in high danger zones that will be useful and valuable in disaster response and wildfire mitigation. And that's where aerial imagery collected by Vexcel Imaging's UltraCam suite of camera sensors comes in.

The Powerful Pairing of Aerial Imagery + Machine Learning

Constantly changing conditions in the world around us have created the need for greater awareness and importance of having accurate, up-to-date understanding of our environment. Aerial imagery is a powerful tool that has long been used to understand what's happening on the ground, to track and monitor change, and to identify areas of

concern. Vexcel Imaging has been the world leader in the field of photogrammetry, creating, developing, and producing market-leading camera sensors that collect multiple layers of geospatial information in high resolution the world over. And now the imagery and data collected from these high-performing camera sensors are being paired with AI and machine learning to uncover key details on the wildfire risk many properties have in fire-prone areas.

Vexcel Data Program, a business unit of Vexcel Imaging, took the superior imagery collected by the UltraCam camera sensors and paired it with machine learning to create Elements, a suite of automated insights on properties and buildings in 30+ countries. One of these insights? Defensible space information, is a critical piece of detail on a property that outlines how many flammable trees sit within four distinct zones around a home at Zone 0-5 foot (1.5 meters), Zone 1-30 foot (9 meters), Zone 2-100 foot (30 meters), and Zone 3-200 (60 meters) foot buffer zones.

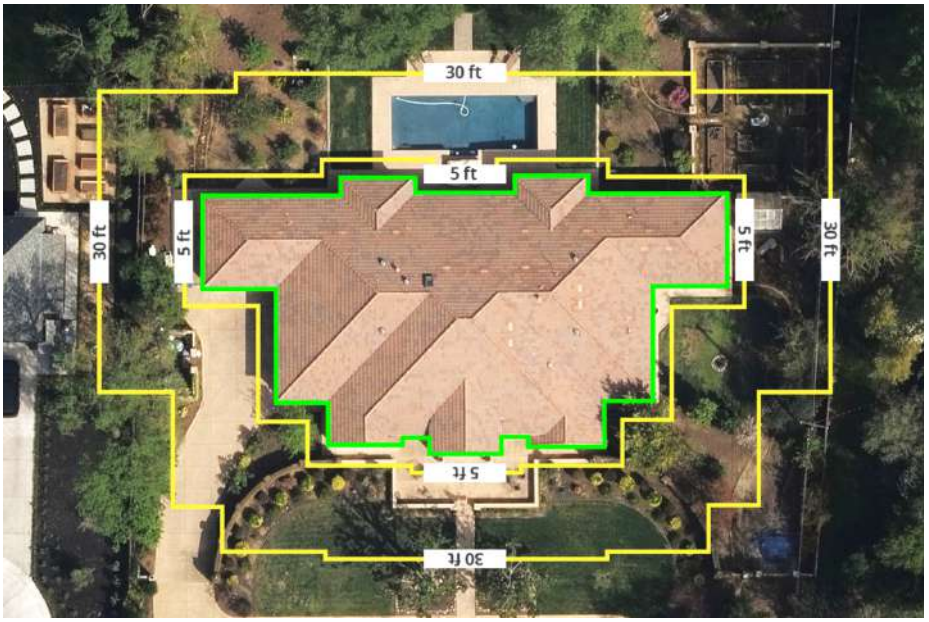


Figure 1: Defensible space zones around a home in California.

Figure 2: Home in Lahaina, Hawaii.

Defensible space information is fast becoming a well-known term for protecting property. What is it? It's essentially the buffer one creates between a building on a property and the grass, trees, shrubs, or any wildland area that surrounds it. The reason why it's so critical and is receiving so much attention, especially in California where Zone 1 and 2 are currently required by law for homeowners to comply with, is this space is needed to slow or stop the spread of wildfire. An example of a home surviving a fast-spreading wildfire by having Zone 0, also called the Ember Resistant Zone, cleared out was evident from the recent Maui wildfires, where a lone home with a red roof remained standing. The owners had removed all foliage up against the house and replaced vegetation near the home with rocks. Little did they know they were creating a barrier that would end up protecting their home from whipping embers.

Categorizing Risk, Optimizing Mitigation

With defensible space information available for every single residential property in the state of California, insurers can pull up detailed information and determine how much risk exists based on the location of a home and the amount of vegetation within each defensible space zone. The next step is putting together a detailed property risk assessment which would include details on where overgrowth could lead to tree, wind, and wildfire damage.

This assessment can then be shared with a homeowner, and together a mitigation plan can be created to reduce the amount of wildfire risk to the property. It's information that not only helps educate an insurer but also a homeowner so both can receive the protection - and awareness - needed to take care of problematic areas before the next fire sparks.

Delivering More Views to Support Better Decision-Making

The mitigation plan can go beyond using just defensible space zone information; it can also address a myriad of challenges or observed issues based on what the high-

resolution aerial imagery shows. Vexcel Imaging cameras collect multiple types of aerial imagery that are useful in creating a narrative around change in and across an environment.

For instance, Multispectral imagery can be a valuable tool in assessing how climate is changing in a particular area. This involves capturing not only visible light in the red, green, and blue spectrums but also a near-infrared channel, which captures light just beyond the wavelengths visible to humans. To make the invisible visible, a colored infrared image can be generated using the near-infrared, red, and green color channels. The final color infrared image makes vegetation and water surfaces easier to see.

With this type of aerial data, end users can extract key information about plant health, soil moisture, water clarity, and wetland mapping. In relation to wildfires, it's one way to observe how much damage to vegetation occurred just at a glance.

Another way color infrared imagery can help support climate change and widespread food insecurity conversations is in the health or growth of green space, whether it be preserving it in densely populated cities, or monitoring the health of vegetation in suburban and rural locations.

Figure 3: Mill Wildfire – California.

Figure 4: Murwillumbah, Australia – flood.

Using Geospatial Data to Support Global Disaster Response

There are more than just wildfires raging in California. As the earth's temperature continues to climb, fires have raged in Canada, Greece, Portugal, Italy, the Canary Islands, and more in recent months. But it's not just wildfires that are impacting communities in multiple areas around the globe. Over the last several years, massive flooding has plagued multiple countries, hurricanes have grown significantly, and tornadoes, tropical storms, and typhoons are all on the rise.

Vexcel Imaging specialized aerial camera sensors have collected disaster imagery after major catastrophes in the U.S., Australia, Germany, Japan, and New Zealand. These high-resolution images have played a vital role in telling a key point in the story of climate change: the intensity of these disasters is only growing. The destruction left after many of these events is crushing from not only a recovery and rebuilding process but also the immense cost perspective and burden that is placed on communities.

Aerial imagery helps communities, builders, emergency responders, urban planners, insurers - anyone - better understand what happened now. And when paired with AI or ML, the data extrapolated from running analytics on disaster imagery can better inform us on which areas are at greater risk, what resources should be deployed, and what types of damage mitigation plans can be put into place.

There are opportunities and a path forward to help address the growing concern of climate change. The next step is taking action by using the tools available before the next big disaster hits.

Reference

[1] Brown, P.T., Hanley, H., Mahesh, A. et al. Climate warming increases extreme daily wildfire growth risk in California. Nature (2023). https://doi.org/10.1038/s41586-023-06444-3

GEO NEWS

September 16 - December 15, 2023

India and US to Enhance Earth Understanding with NISAR Satellite Launch in Early 2024

In a landmark collaboration, India and the United States are set to launch NISAR, a joint microwave remote sensing satellite for Earth observation, in the first quarter of next year, as announced by Union Minister Dr Jitendra Singh during a meeting with a high-level delegation of NASA led by its Administrator Mr Bill Nelson. NISAR is scheduled to be launched aboard India's GSLV. The information gathered by NISAR will be particularly valuable for examining land ecosystems, solid earth deformation, mountain and polar cryosphere dynamics, sea ice variations, and coastal oceans on a regional to global scale

Collaboration Between Survey of India and Genesys for Advanced 3D Digital Twin-Mapping Initiative in India

Genesys International, a domestic mapping firm, has entered into a partnership with Survey of India to harness its capabilities in creating 3D digital twins for significant towns and cities across the nation. Through this collaboration, Genesys International will tap into the technological and data assets accumulated by Survey of India since its inception in 1767. Hitesh Kumar Makwana, the Surveyor General of India, highlighted that this marks the inaugural Memorandum of Understanding (MoU) between the department and a private enterprise for the advancement of geospatial content.

Trimble Support for India's Commitment to the UAV Industry

Trimble has announced a collaboration with the Indian Institute of Technology in Kanpur (IIT Kanpur) to support a new program in UAV to be offered by the Department of Aerospace Engineering. A signing ceremony to officially launch the program was held on October 26 and attended by Professor Tarun Gupta, dean of research and development; Professor Onkar Dikshit; Professor Bharat Lohani; Major General Dr. B. Nagarajan; and Professor Salil Goel from IIT Kanpur. In attendance from Trimble were Rajan Aiyer, managing director, India; and Sanjeev Trehan, director, business development and sales. Trimble has contributed direct georeferencing (DG) products for UAV survey and mapping to the institution. This includes a suite of Applanix board sets and the supporting processing software.

Union Minister Dr. Jitendra Singh Launches CORS Network Operated by Survey of India

In a significant stride towards bolstering India's geospatial infrastructure, Union Minister Dr. Jitendra Singh has inaugurated the nationwide CORS network operated by Survey of India. The cutting-edge initiative, known as the "Continuously Operating Reference Stations" (CORS) Network, is set to revolutionize the country's surveying and mapping capabilities. Speaking at the occasion, Union Minister Dr. Jitendra Singh emphasized the critical role of advanced geospatial data in various sectors, including urban planning, agriculture, disaster management, and infrastructure development.

Esri Integrates with Microsoft Fabric to Deliver Leading Spatial Analytics Capabilities

To meet the growing demand for spatial analytics, Esri is extending its long-standing strategic collaboration with Microsoft through a unified analytics platform powered by spatial capabilities. Microsoft Fabric, now in General Availability as announced at Microsoft Ignite, will accelerate time to insights and reveal unexplored patterns, trends, and connections through the integration of spatial analytics from Esri's ArcGIS software. Data scientists, data engineers, business analysts, and their executive stakeholders demanding spatial analytics and visualization within Fabric will benefit greatly from the joint offering. Esri's ArcGIS integration will allow data to flow across an organization, whether working from Microsoft OneLake, Microsoft Power BI, or their ArcGIS environment. Fabric users will be empowered with direct access to sophisticated spatial analytics tools.

New *RIEGL* Laser Scanning Solutions for UAV-based Data Acquisition

With their latest developments, *RIEGL* once again underlines its pioneering role as a provider of high-performance LiDAR sensors and systems for integration with UAS. The new *RIEGL* VUX-18024 offers a wide field of view of 75 degrees and an extremely high pulse repetition rate of up to 2.4 MHz. The *RIEGL* VUX-24024 is the new enhanced version of the *RIEGL* VUX-240, now offering higher pulse repetition rates and faster scanning speed. In addition to the stand-alone versions of the *RIEGL* miniVUX-1UAV and the miniVUX-3UAV LiDAR sensor, *RIEGL* also offers system solutions with IMU/GNSS systems and cameras. Now *RIEGL* provides RiLOC, an integrated component to complement *RIEGL*'s kinematic LiDAR systems for localization and orientation of LiDAR data in a reference coordinate system. This fully integrated subsystem with a small and lightweight form factor is directly attached to the housing of the miniVUX-1UAV or miniVUX-3UAV.

Carbonix, Woolpert Employ Cutting-Edge Drone to Collect Geospatial Data for Coal Mine Rehabilitation

Leading Australian drone manufacturer and solutions provider Carbonix is collaborating with global aerial survey specialist Woolpert to assist with the rehabilitation of one of New South Wales' oldest open cut coal mines, using cutting-edge drone and geospatial data capture technology to help in this transition.

Esri and National Geographic Society Launch National Geographic MapMaker

By learning about mapping skills and geography, students, teachers, and others can gain a better understanding of how the world's most crucial issues, challenges, and opportunities fit into the context of place. In celebration of GIS Day and as part of Geography Awareness Week, Esri, the global leader in GIS technology, and the National Geographic Society, the global nonprofit organization, have launched the reimagined National Geographic MapMaker. With this web-based 2D and 3D app, anyone can visually experience and interact with geospatial information.

GEOSAT Announces New Constellation, Reinforcing Its Global Position As A European Operator Of Very High-Resolution Satellites

GEOSAT announces the launch of its future constellation of Earth Observation satellites, thus reinforcing its exclusive position in Europe as one of only two European companies with very high-resolution satellites. By 2025, GEOSAT intends to launch 11 new High and Very High-Resolution satellites. There will be 8 high-resolution satellites for revisiting every 6 hours, and 3 very high-resolution satellites (50cm), for a total investment of 100 million euros.

BAE Secures $183M NGA Analytic Modeling Capability Development Contract

BAE Systems has received a potential five-year, $183 million contract from the National Geospatial-Intelligence Agency for GEOINT modeling support services. The company will develop, integrate and provide sustainment support for analytic modeling capabilities under the indefinite-delivery/indefinite-quantity contract.

Trimble Precise Positioning Engine Receives ASIL-C Certification, Supporting Safety-Critical Applications for ADAS and Autonomy

Trimble has announced the ISO 26262:2018 Automotive Safety Integrity Level-C (ASIL-C) certification of its automotive and heavy trucking precise positioning engine - ProPoint Go™. ProPoint Go is the first precise positioning engine to be ASIL-C certified. Designed to respond to the most challenging automotive requirements, Trimble ProPoint Go provides centimeter-level precise and reliable position, velocity and time information based on multi-frequency GNSS signals and ASIL-B certified Trimble RTX® correction data. Automotive manufacturers and suppliers can now utilize precise positioning technology that has been validated for use in safety-critical applications such as advanced driver-assistance systems (ADAS).

KUFOS Develop Spectral Library of Uma Rice

In an attempt to enhance precision farming and improve crop management strategies, the Kerala University of Fisheries and Ocean Studies (KUFOS), in association with the Centre for Water Resources Development and Management (CWRDM) has developed a spectral library for Uma rice, a popular indigenous rice variety in Kerala, using space technology. The newly developed spectral library for Uma rice will help to enhance precision farming practices and contribute to improved crop management strategies, said KUFOS Vice Chancellor T. Pradeepkumar.

Trimble Partners with HALO Trust for Landmine Clearance in Ukraine

Trimble and the Trimble Foundation Fund have partnered with The HALO Trust, the world's largest landmine-clearing non-profit organization, to help expand its demining operations across Ukraine. The Foundation Fund directed grant focuses on strengthening the HALO Trust's capacity to locate and remove landmines, unexploded ordnance, and other explosive hazards from civilian areas to create safer communities.In addition, the Trimble Foundation Fund grant also enables HALO to support the Ukrainian national authorities to plan and coordinate landmine clearance activities by streamlining the mapping and data flow from the operational teams in the field to the national database.

Geospatial Tech Company Aerometrex Lands $1m Contract to Monitor Great Barrier Reef

Adelaide-based geospatial data company Aerometrex has secured a $1 million contract with the Queensland Government to survey and monitor the Great Barrier Reef using laser scanning technology. The project involves the use of a remote sensing method known as Light Detection and Ranging (LiDAR), which utilises laser beams to create an accurate 3D representation of a surveyed environment. The survey will map key areas of the Great Barrier Reef catchments, including Burdekin, Wet Tropics and Fitzroy areas, and assess the state of gully and streambank erosion, monitoring change over time.

Leica BLK2GO PULSE Wins CES Award

Leica Geosystems has been named a CES 2024 Innovation Awards Honoree for the Leica BLK2GO PULSE. The CES Innovation Awards is an annual competition honouring outstanding design and engineering in consumer technology products across 29 product categories. The program was ALL ON for CES 2024, receiving more than 3,000 submissions, a record high and a 40% increase over CES 2023.

Trimble Introduces Automatic Stream Switching, Allowing Seamless Centimeter-Level Accuracy Via Satellite and Cellular

Trimble has announced stream switching - a new feature allowing farmers to seamlessly stream Trimble CenterPoint® RTX, RangePoint® RTX and ViewPoint RTX®, over IP or satellite. Available for farmers using a NAV-900 or NAV-500™ receiver, this new feature delivers less down time and performance comparable to RTK without the complexity of base stations.

Hamburg Chooses Hexagon Solutions to Modernize Police and Fire Operations

Hexagon's Safety, Infrastructure & Geospatial division announced the Free and Hanseatic City of Hamburg, Germany, has selected HxGN OnCall solutions to modernize emergency dispatch operations and analysis for the city's fire and police departments. The modernization, part of Hamburg's PERLE program (Programm Erneuerung Leitstellen von Feuerwehr und Polizei), will bring cutting-edge technologies to Germany's second largest city.

GPS-based Toll Collection Systems To Be Replaced At Toll Plazas Soon

India, in a move aimed at reducing traffic congestion and charging motorists for the exact distance travelled on the highways, GPS-based toll systems to replace toll collection plazas in the country. GPS based toll collection will differ from FASTag because it will track you throughout. Automatic deduction in FASTags happens only when you approach the toll plaza. The government will introduce new technologies including GPS-based toll collection systems in the next 6 months to replace existing highway toll plazas in the country, Union minister Nitin Gadkari said.

Trimble to Provide Advanced Positioning Systems to Sabanto for Autonomous Tractor Performance

Trimble and Sabanto have announced the integration of Trimble BX992 Dual Antenna GNSS receivers with Trimble CenterPoint® RTX into Sabanto's autonomy solutions. Trimble will act as Sabanto's key autonomous technology provider, delivering high-accuracy positioning to its fleet. Farmers need the highest level of uptime and reliability to avoid service disruption. Leveraging Trimble's BX992 GNSS receiver and satellite-delivered Trimble CenterPoint RTX corrections service, Sabanto's autonomy solutions can now receive centimeter-level L-Band corrections nearly anywhere in the world.

New AI-powered Space Technology Company Launches in Abu Dhabi

Following the recent announcements made by Bayanat AI PLC (Bayanat) and Al Yah Satellite Communications Company (Yahsat) regarding their proposed merger, the two Abu Dhabi-based entities listed on the ADX have recommended the merger to their shareholders. The combined entity resulting from the merger will be known as Space42. The company's implied market capitalization stands at 15 billion dirhams ($4 billion).

Bluesky Partners with Sensat Providing Data for New Visualisation Tool

A new data visualisation tool designed to support civil infrastructure teams expediate access to data during the planning phase enabling more informed decision making and significant reductions in time and resources has been developed and launched. Bluesky International and Sensat have entered into a partnership to merge rapid data collection methods and advanced visualisation capabilities, unlocking data certainty for infrastructure teams.

Topcon Joins Septentrio's Agnostic Corrections Partner Program

Septentrio has recently announces that Topcon Positioning Systems is joining their Agnostic Corrections Partner Program. This program was launched earlier this year to facilitate the use of Septentrio receivers with various high-accuracy services, offering integrators the flexibility to choose the most suitable correction service for their specific application. Topcon's Topnet Live is a real-time GNSS corrections service that delivers high-quality centimeter-level RTK corrections data with a broad worldwide network coverage.

Woolpert Awarded $13M Contract to Collect Bathymetric Lidar Data for Florida Seafloor Mapping Initiative

The Florida Department of Environmental Protection has tasked Woolpert with acquiring bathymetric survey data using lidar technologies to support the Florida Seafloor Mapping Initiative (FSMI) and its mission to produce a comprehensive, publicly available, high-resolution seafloor surface model of Florida's coastal waters by 2026. The data will be used to help evaluate the performance of restoration projects and support coastal resilience efforts.

PRODUCT LAUNCH

September 16 - December 15, 2023

Trimble Launches New IonoGuard Technology to Mitigate Ionospheric Disruptions

Trimble has introduced Trimble IonoGuard™, a next-generation technology designed to mitigate ionospheric disruptions in positioning and navigation by minimizing performance impacts caused by scintillation or signal noise. Available as a downloadable firmware update on Trimble GNSS receivers utilizing the Trimble ProPoint® GNSS positioning engine, IonoGuard leverages the latest developments in Trimble's high-precision receiver hardware design and signal tracking to deliver improved positioning performance in challenging environments. This will minimize the probability of a complete loss of GNSS signals and improve the quality of the signals' accuracy and integrity.

K-Smart Online Platform to 'Know Your Land' in Kerala

K-Smart, the online platform set to be launched on January 1 in urban local bodies in Kerala India, will replace all the major existing stand-alone websites for government services and promises a more integrated, user-friendly experience. It will integrate nine major citizen services including civil registration (issuing of birth, death and marriage certificates), issuing of building permits, trade licences, payment of property taxes and public grievance redressal, bringing down drastically the time taken in getting some of these services.

Ministry Of Mines, Unveils Portal For Innovative Geoscience Exploration

The Ministry of Mines, Government of India marked a historic moment with the launch of the National Geoscience Data Repository (NGDR) Portal. This initiative, spearheaded by the Geological Survey of India (GSI) and Bhaskaracharya Institute of Space Applications and Geoinformatics (BISAG-N), is poised to revolutionize access to critical geoscience data. The NGDR Portal is poised to play a transformative role in shaping the future of geospatial information management in India.

Leica Geosystems Brings Leica BLK2GO PULSE

Leica Geosystems has announced the upcoming release of the Leica BLK2GO PULSE. The BLK2GO PULSE is a new first-person laser scanner that combines cutting-edge LiDAR sensor technology with the original Leica BLK2GO form factor. It provides customers with a rapid, simple and intuitive first-person scanning method, controlled with their smartphone, that delivers full-colour 3D point clouds instantly in the field.

ALDOT Uses SimActive Software to Support Tornado Recovery

SimActive Inc. announces the use of Correlator3D by the Alabama Department of Transportation (ALDOT) to process drone imagery for damage assessment. Earlier this year, a powerful tornado ripped through the southwest portion of the city of Selma in Alabama. ALDOT quickly collected more than 18,000 images of the area and within 24 hours, processed the data using SimActive software and delivered digital surface models and orthomosaics.

Avenza Releases MAPublisher 11.3 for Adobe Illustrator

Avenza Systems Inc., producers of the Avenza Maps® app for mobile devices and geospatial extensions for Adobe Creative Cloud®, including Geographic Imager® for Adobe Photoshop®, is pleased to announce the release of MAPublisher® version 11.3 for Adobe Illustrator®. This version offers full compatibility with Adobe Illustrator 2024 (version 28), macOS Sonoma (version 14), and the FME Auto 2023 update. It also includes performance enhancements and bug fixes.

Hexagon Expands TerraStar-X Precise Positioning GNSS Correction Service to South Korea

Hexagon's Autonomy & Positioning division and Munhwa Broadcasting Corporation (MBC) proudly announce their agreement to bring precise positioning to South Korea through the TerraStar-X Enterprise Correction Service. The hardware-agnostic correction service provides instant convergence and lane-level accuracy in automotive, mobile and autonomous applications.

GEO EVENTS

February 11 – 13, 2024
Geo Week
Denver, CO, USA
https://www.geo-week.com/

March 12 – 15, 2024
Esri Developer Summit
Palm Springs, CA, USA
https://www.esri.com/en-us/about/events/devsummit/overview

April 29 -30, 2024
IGRSM Conference
Austin, TX, USA
https://conference.igrsm.org/igrsmc2024/

May 2 - 4, 2024
GISTAM 2014
Angers, France
https://gistam.scitevents.org/

May 5 - 8, 2024
GEOINT 2024 Symposium
Kissimmee, FL, USA
https://gistam.scitevents.org/

May 13 -16, 2024
Geospatial World Forum
Rotterdam, The Netherlands
https://geospatialworldforum.org/

July 15 -19, 2024
Esri User Conference
San Diego, CA, USA
https://www.esri.com/en-us/about/events/uc/overview

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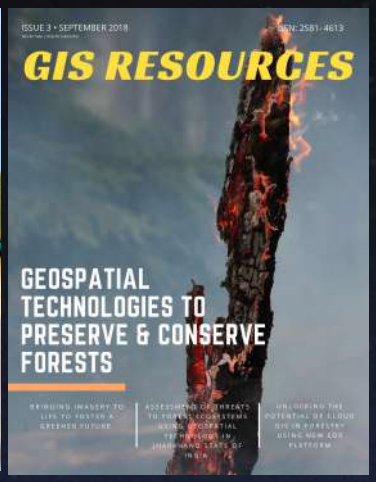

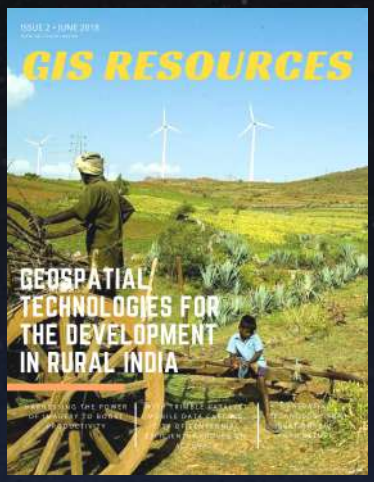

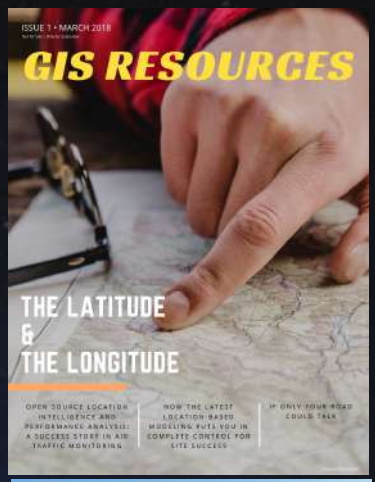

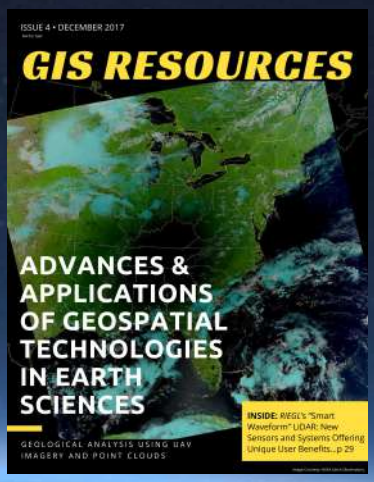

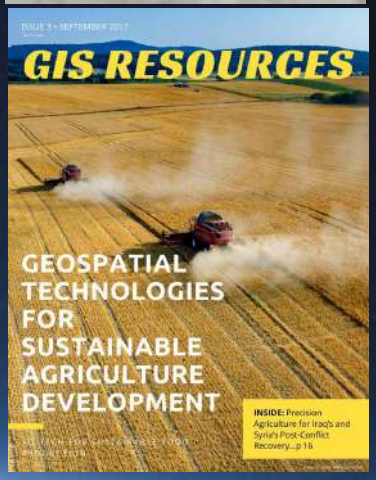

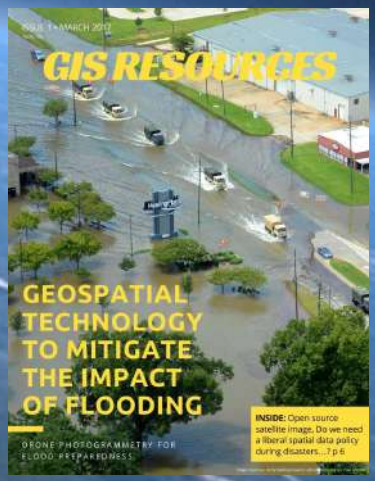

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