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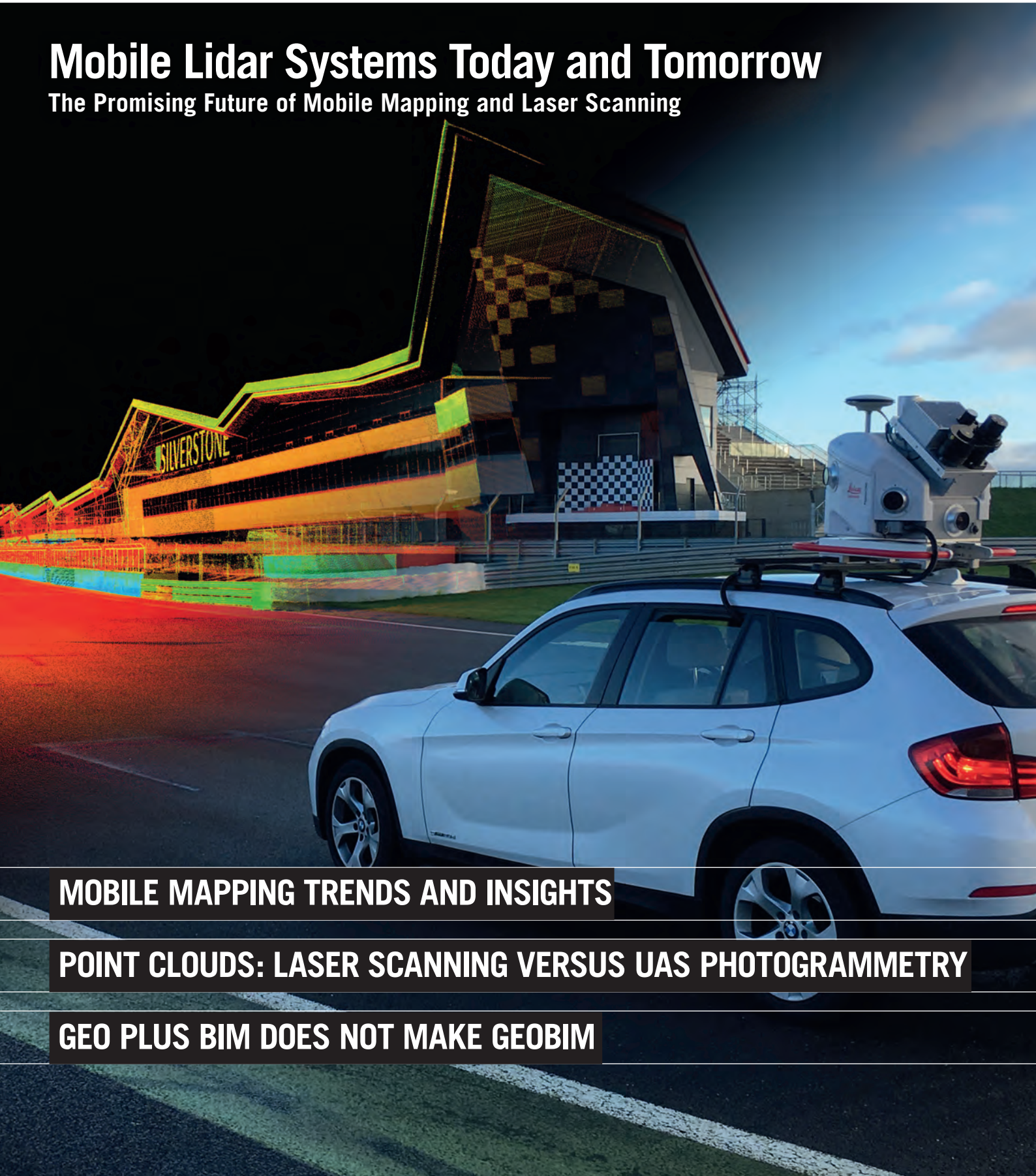
Mobile Lidar Systems Today and Tomorrow

The Promising Future of Mobile Mapping and Laser Scanning



MOBILE MAPPING TRENDS AND INSIGHTS

POINT CLOUDS: LASER SCANNING VERSUS UAS PHOTOGRAMMETRY

GEO PLUS BIM DOES NOT MAKE GEOBIM

GIM INTERNATIONAL

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COVER STORY

The front cover of this July/August issue of *GIM International* shows a mobile mapping project at Silverstone, a motor racing circuit in England and current home of the British Grand Prix. The mobile mapping survey was conducted with the Leica Pegasus:Two. This solution delivers an integrated hardware platform which includes cameras and Lidar profilers with an exterior activate and sync output for further sensors. Mobile mapping is one of the key topics in this edition.
Image courtesy: MK Surveys (www.mksurveys.com)

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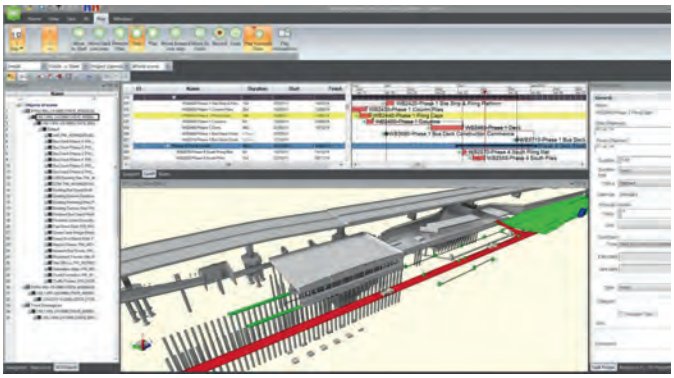
Bentley Systems Acquires Synchro Software



Synchro 4D construction modelling of Crossrail Station.

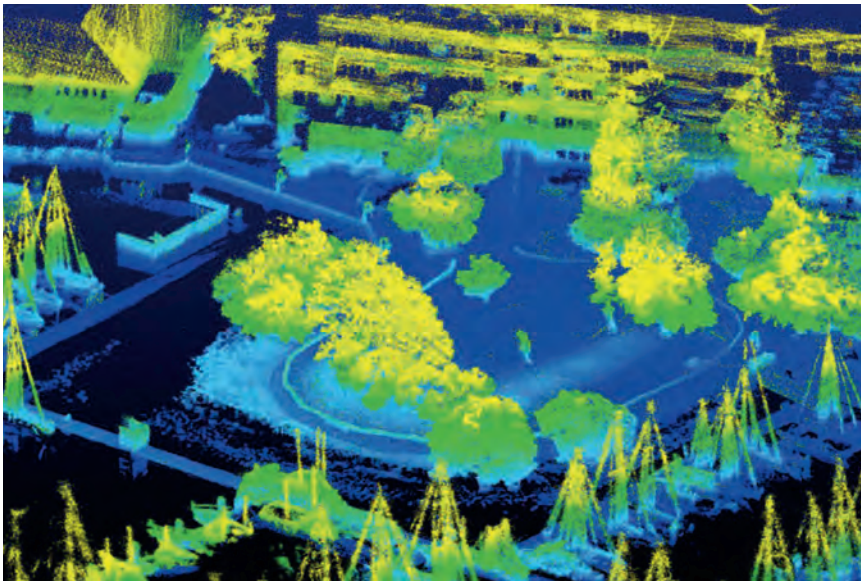
Bentley Systems has announced the acquisition of Synchro Software, specialised in 4D construction modelling software for scheduling and project management. Synchro, which can be described as a 'construction time machine', has been globally adopted, in particular, for building and civil infrastructure projects. The acquisition broadens Bentley's ProjectWise construction offerings, which already include ConstructSim, a solution for 4D construction modelling in project delivery of industrial plants. With construction project management in 4D, benefits of BIM can extend throughout infrastructure project delivery and asset life cycles, as traditionally disconnected workflows become digital workflows.

▸ **https://bit.ly/2MM6noe**

Lidar Market Heading towards 2 Billion Dollars by 2023

According to a comprehensive new market research report, the overall Lidar market is expected to reach over US$1.8 billion by 2023, up from US$819.1 million in 2018, at a CAGR of 17.2%. Encouragement from the governments and institutes for the adoption of Lidar while conducting geological surveys is the major factor driving the growth of this market. Introduction of technologically enhanced Lidar is also fuelling the market. The report, titled 'LiDAR Market by Type (Mechanical LiDAR and Solid-State LiDAR), Installation (Airborne and Ground-Based), Application (Corridor Mapping, ADAS & Driverless Car and Engineering), Range, Component, Service and Geography – Global Forecast to 2023' is published by MarketsandMarkets.

▸ **https://bit.ly/2tP5HpA**



Lidar imagery, captured by Velodyne LiDAR technology.

Mission accomplished

One of the bravest and maybe toughest decisions in the geospatial environment over recent weeks has been the winding up of the operations of the Global Spatial Data Infrastructure (GSDI) Association. The association has existed for more than 20 years and delivered conferences, provided funding and facilitated extensive knowledge-sharing across an international network of geospatial professionals. GSDI President Dave Lovell explains the discontinuation of the activities as recognition that its vision and mission have been adopted by organisations like the United Nations in UN-GGIM, the World Bank and the Open Geospatial Consortium. GSDI will use the remaining funds to support underdeveloped parts of the world in taking part in initiatives like UN-GGIM. Not many organisations dare to take such a thorough look at themselves and conclude 'We've achieved our mission, we've become superfluous'. I admire such brave action, especially when there are so many associations, networks and societies who wouldn't even consider such a step. In an era when resources are scarce, unnecessary travel around the world to meet each other is almost a crime against the climate and modern technology offers an abundance of possibilities to communicate and collaborate, it's perhaps time to jump over one's own shadow and think about other ways of reaching goals for putting geospatial data to work for a better world. GSDI, many thanks for your good work and rest assured that your message has landed in many hearts and minds!

Durk Haarsma, director strategy & business development

Mobile Mapping

The demand for detailed, up-to-date 3D maps of cities, roads and large buildings is steadily growing. This demand is nourished by the ongoing exponential decrease in the cost of collecting point clouds (PCs). A major source of PCs are mobile mapping systems (MMSs), usually mounted on a car, van or other vehicle that can travel at the normal speed of traffic on roads and highways. An MMS usually consists of a positioning and orientation system, one or more laser scanners, one or more digital cameras and a control unit. However, the ongoing miniaturisation of sensors and electronics is leading to the construction of laser scanners which are light enough to be mounted on unmanned aerial systems (UASs), trolleys, backpacks or sticks. The stick can be held in a surveying layman's hand to capture rooms, corridors and many other indoor spaces and outdoor scenes. Many construction engineers, facilities managers and architects already acquire dense points by walking through the scene with just a handheld laser scanner on a stick. Hence, the acquisition of point clouds is no longer the sole domain of geomatics specialists. The key to this are easy-to-use, reliable sensors accompanied by robust software. Operating in buildings, tunnels and mines requires advanced solutions since there is no GNSS coverage. As a result, the role of the geomatics specialist is shifting from surveyor to advisor and software developer. An essential part of the knowledge spectrum concerns the understanding of the nitty-gritty of geospatial datasets, their fusion with other data as well as the storage demands of big data.

Mathias Lemmens, senior editor

How to get more out of Intergeo

The northern hemisphere may be in a state of collective holiday mood as summer is now in full swing, but for geomatics professionals it is wise to start looking ahead to the autumn already. From 16-18 October, Intergeo will take place in Frankfurt, Germany. During these three days, Europe's financial centre will also be the epicentre of the mapping and surveying world. If your company is exhibiting at Intergeo, why not team up with *GIM International* to get the most out of this leading geospatial trade show? We can help you to grow your business in a multitude of ways. For example, we can develop and schedule a campaign that puts your products in the spotlight, building extra awareness before and during Intergeo. Through our various channels and marketing solutions, we can support your company's presence by creating the right buzz just before you head to Frankfurt. That extra exposure will attract more people to your booth – and hopefully lead to some valuable business... You can depend on our team of advisors who have proved themselves to be key marketing partners for many prominent companies in our wonderful industry.

Want to learn more? Contact our marketing advisors:
Thomas Stuiver (Europe, Middle East, Africa) - thomas.stuiver@geomares.nl
Sybout Wijma (Rest of the world) - sybout.wijma@geomares.nl

Besides the exhibition comprising several halls filled with a staggering number of booths in all shapes and sizes where companies present their latest innovations, Intergeo also encompasses a conference programme. I am proud to announce that *GIM International* will be organising one of the conference sessions. Rest assured that this will be a must-attend event, with keynote speakers such as Christoph Strecha, CEO and founder of Pix4D, who will deliver a talk on 'The impact of AI and machine learning on geospatial data', and Gerd Hesina, CEO of VRVis. Make sure you block **Thursday 18 October** from **11:00-12:30** in your diary!

Wim van Wegen, content manager

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Geo Plus BIM Does Not Make GeoBIM

The added value of integrating geoinformation (Geo) with building information modelling (BIM) to solve contemporary multidisciplinary challenges of our urban environment is widely recognised.
An architect (BIM) can take environmental information (Geo) into account while designing a building, and a municipality can then automatically check the design (BIM) against its environmental impact (Geo), such as whether it is below the maximum building height, the level of noise exposure for residents, and how much solar irradiation the building will receive. Building permission procedures will thus become both faster and more reliable. Furthermore, 3D city models will be more detailed and up to date; the design of a permitted construction or building is a source for the 3D city model, with added information such as building materials and energy-related attributes that can be used for the construction's life-cycle management.

It seems straightforward. Much research and many projects have shown how geodata has been successfully used in design and construction activities, how BIM data serves as source for geodata, and how BIM semantics (as defined for example in the IFC standard) map to geo semantics (as defined in, for example, CityGML). But in practice IFC models are not structured according to these mappings. In addition, the fundamental differences between BIM and Geo geometry models have hardly been investigated until now. With over a thousand IFC classes available, there are many different ways to model a specific situation, which makes it impossible to develop a uniform translation that works for any IFC model. How can we translate the hundreds and often even thousands of constructional elements (modelled as volumes) that together define a house in a BIM model into a single, closed building object, defined with surfaces as required for geospatial analysis?

The Open Geospatial Consortium (OGC) confirmed these challenges in a project on the use of IFC and CityGML in Urban Planning . OGC identified inconsistencies in coding IFC elements that complicate the transformation to CityGML and concluded that, in order to adopt IFC in urban planning, a clear set of specifications needs to be set for the preparation of IFC files.

Another problem is that IFC models from practice contain errors, making it hard to use them in spatial analysis. In a project in The Netherlands with stakeholders from both domains , invalid objects were found to be widespread in the IFC models that are obtained from architectural and design software. Interestingly, some errors were disallowed by the IFC standard, but not enforced by most current implementations. Users of the software have little notion of this problem, but these errors make it hard to reuse the data in other software.

Mainstream software vendors have partly solved the interoperability problem between their proprietary formats, but this is not sufficient for a fundamental Geo and BIM integration.
In addition, with IFC mainly covering buildings until now, little is known about the Geo and BIM integration for infrastructure (currently being standardised in IFC). For example, how can 3D profiles of roads, generated in BIM by extruding a profile along a 2D road axis, be understood outside the software in which they are generated?

Models of buildings are produced in both domains for different purposes, such as for design and construction in BIM and for geospatial analysis in GIS. The question of how the data can be better reused is difficult to answer as long as there is insufficient knowledge of where Geo and BIM data should or could meet in practice, and how fundamental solutions can be developed accordingly.
Many experts are knowledgeable in only one of the two domains, and professionals who understand the data needs, the work processes, the techniques, the software and the standards in both domains are rare. To bridge this fundamental knowledge gap, a EuroSDR collaboration between 11 national mapping and cadastral agencies will analyse two use cases in detail by intensively involving the stakeholders: a) the workflow from global design to a building permit, and b) the workflow of the object life cycle in asset management. Which process steps and information flows do these use cases have or wish to have, and what are the needs at every step to use Geo data in a BIM environment and vice versa? To what extent does BIM software support Geo data and vice versa, and what further developments are required? What agreements are needed on geometric definitions to make the level of development of the models interoperable, and levels of detail useful to both? How can the reuse of Geo data and BIM data in these use cases be improved beyond the exchange of data between a few professionals or between the main software vendors?

The result will be a 'best practice for Geo data in a BIM environment' and a 'best practice for BIM data in Geo information', a contribution from an international perspective to fulfil the promises of Geo and BIM integration.

Jantien Stoter.

ABOUT THE AUTHOR

Prof Dr **Jantien Stoter** chairs the 3D Geoinformation research group at the Delft University of Technology (Faculty of the Built Environment and Architecture). She also works as an innovation advisor at both Kadaster and Geonovum. Jantien did her PhD on 3D Cadastre (2004), received a prestigious grant of the Dutch Science Foundation on 5D modelling (2011) and was recently awarded a grant from the European Research Council for research into urban modelling in higher dimensions. She leads and co-leads several studies on Geo and BIM integration, one of which is the EuroSDR GeoBIM project.
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Airbus Partners with Planet for Satellite Imagery

Airbus and Planet signing the partnership agreement.

Airbus has announced a data-sharing agreement with satellite imagery purveyors Planet, along with a project to deliver a geoinformation platform and pipeline for the Thai government. The depth and breadth of satellite data products in the marketplace may soon expand following the announcement by Airbus and Planet of a new partnership that provides access to each other's data, and an agreement to co-develop new products. Airbus says the partnership aims to address the growing demand for continuous monitoring and accurate information, and the relative strengths of both companies' infrastructure and data assets should result in some unique and powerful offerings.

▸ **https://bit.ly/2lEqLLM**

YellowScan Crosses the Ocean with UAV-Lidar Solutions

YellowScan, a designer, developer and producer of UAV-Lidar solutions for professional applications, continues to expand its presence in the USA with the opening of a new office located in Salt Lake City, Utah. The expansion will allow YellowScan to continuously serve its growing list of customers within the USA and Canada with first-hand local and tailor-made services for this market. In addition to the corporate headquarters in Montferrier-sur-Lez near Montpellier (France), the new office supports the company's growth strategy. General manager, Cliff Holle, is set to head operations at the US branch. Holle brings over 20 years of experience and tactical know-how of the North American market.

▸ **https://bit.ly/2lFLvCJ**

YellowScan combines UAV and Lidar.

Streaming Massive City Datasets to Mobile AR and VR

Real-time streaming 3D model of Helsinki.

Umbra, a company specialised in creating 3D content in real time, has partnered with the City of Helsinki, Finland, to bring a massive, real-time streaming 3D model of the entire city online and make it viewable on mobile devices and web browsers. The reality mesh model of Helsinki is based on aerial photographs of the city taken in the summer of 2015. Helsinki generated an enormous point cloud, representing a 50km^2 area of the city, then processed that data into a 700GB texture-mapped 3D mesh. The City of Helsinki's goal was to make this open dataset available for anyone to use, but the sheer size and complexity of the 3D data presented an insurmountable challenge. At that point the city spoke with Umbra about using its automated optimisation on the dataset to make it easily deliverable. Umbra optimised the mesh using its fully automated cloud platform that can now stream the entire dataset to augmented reality-capable or virtual reality-capable mobile platforms such as smartphones, tablets, headsets and even web browsers.

https://bit.ly/2tFkrYB

Delair Expands Canadian Presence with New Distribution Agreement

Delair, a leading global supplier of commercial UAV solutions, has entered into an agreement with Cansel, a full-service provider of surveying and mapping solutions to the Canadian market. Cansel has now become the first Canadian reseller of Delair's innovative Delair UX11 long-range drone, and the two companies plan to rapidly expand the agreement to include the entire Delair product line. In addition, Delair confirmed that its entire portfolio of fixed-wing drone products has been certified as compliant by Transport Canada under its regulation of the UAV sector. Cansel is a certified drone operator per the regulations of Transport Canada, the government agency responsible for UAV operations, a status which requires the use of certified drone products.

https://bit.ly/2IBxZJn

Delair UX11 mapping UAV.

DroneDeploy Releases Real-time Thermal Mapping for Commercial UAVs

DroneDeploy Thermal Live Map.

DroneDeploy, an unmanned aerial vehicle (UAV or 'drone') software company with the largest drone data platform in the world, has announced the launch of Thermal Live Map, a real-time mobile mapping solution which delivers insights only thermal imagery can reveal. A first-of-its-kind feature, Thermal Live Map visualises temperature range variability and creates instant thermal maps for quick, data-guided decisions on the job site. Traditionally thermal inspections have been time-consuming, limited to accessible areas, or have required manned aircraft that typically yield low-resolution data at a high price. DroneDeploy's Thermal Live Map solves these issues by providing immediate visual context to situations unseen by the naked eye – all without a computer, SD card or internet connection. The new solution uses the latest advancements in edge computing to generate thermal drone maps locally on iOS devices as a DJI drone flies.

https://bit.ly/2Kvt6Xb

EuroGeographics Signs Production Agreement with Germany's Federal Agency for Cartography and Geodesy

BKG will coordinate technical production and quality management.

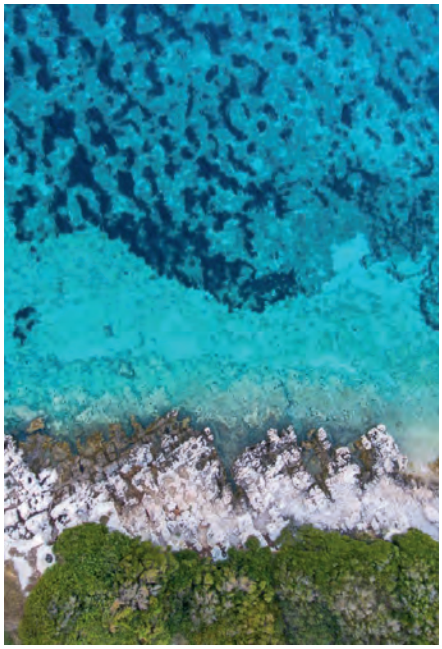
EuroGeographics is developing a new core reference dataset using INSPIRE-compliant geospatial information from official national sources. The international not-for-profit membership organisation for Europe's National Mapping, Cadastral and Land Registration Authorities (NMCAs) has signed an agreement with Germany's Federal Agency for Cartography and Geodesy (BKG) to coordinate technical production and quality management. A prototype, focusing on transportation (road and railway) and hydrography themes, is to be available in Autumn 2018 and will also include basic feature types and attributes. This will be followed by the launch of the first version of the new dataset in Spring 2019.

https://bit.ly/2tQmoRI

Token Generation Event to Fund Decentralised Global Super-map Using Drones

Australian geospatial mapping technology company Soar has announced its highly anticipated Token Generation Event (TGE) designed to fund the launch of the world's first decentralised global platform for the distribution of unmanned aerial vehicle (UAV or 'drone') content and maps. The TGE will be facilitated by an international consortium of blockchain advisors including Fidem and Digital Capital Management. The Soar TGE is expected to raise up to US$20 million through the sale of its SKYM token and has already secured several cornerstone investments from technology funds including Lateral Capital Ventures, Peregrine Corporate, Alium Capital and Otsana Capital. Soar's stage 1 is the initiation of its global drone content marketplace platform, which company founder and CEO Amir Farhand believes will be the go-to place for almost any content that drones produce at both consumer and commercial levels. According to Farhand, both professional and hobbyist drone operators will be able to monetise unused content, the majority of which is sitting on old hard drives and forgotten. They have already onboarded over 450 drone operators globally, and this still is just scratching the surface of this opportunity, he said.

▸ **https://bit.ly/2ILeHIp**



Drone imagery as provided by the Soar platform.

360-degree Big Data Capture on the Move

iSTAR Pulsar mounted on a vehicle.

Whether from the air, by car or on foot – the ability to capture 360-degree images on the move to create immersive virtual environments is becoming increasingly desirable in many applications. From urban planning and city asset management, to transportation analytics and crowd flow monitoring, big imaging data can empower many aspects of the modern smart city. Recently, NCTech – an Edinburgh-based developer of reality imaging systems – announced the availability of iSTAR Pulsar, a professional edge-to-cloud big data system optimised for capture on the move. Developed in association with Sony and Intel, iSTAR Pulsar is specifically designed to capture 360-degree data while mounted on a vehicle or drone or used on foot. The system is designed for ease of use and does not require any photography experience or even a computer to operate. The iSTAR Pulsar app provides the ability to plan routes, as well as to view and share content online.

▸ **https://bit.ly/2MtXNtl**

OGC Calls for Participation in Indoor Mapping and Navigation Pilot

The Open Geospatial Consortium (OGC) has released a Call for Participation to solicit proposals for the OGC Indoor Mapping and Navigation Pilot initiative. The Indoor Mapping and Navigation Pilot, sponsored by the Public Safety Communications Research Division of the National Institute of Standards and Technology (NIST), will create and advance solutions to complex geospatial challenges related to indoor mapping and navigation for first responders. First responders typically survey high-risk facilities in their jurisdiction at least once per year as part of a preplanning process. Outputs from preplanning are often in report form, and first responders may annotate available floor plans (e.g. from computer-aided design models) or generate their own hand-drawn maps during the process. Preplanning is time-consuming, inefficient and inherently complex, considering the information and level of detail that should or could be captured, the lack of automation and the difficulty identifying notable changes to facilities and infrastructure during successive preplanning surveys.

▸ **https://bit.ly/2tQQ1lu**

Accurate Georeferencing for UAV Surveying without Base Station

Klau Geomatics, specialised in post-processed kinematic (PPK) direct georeferencing technology, has announced its new No-Base-Station high-accuracy georeferencing solution for unmanned aerial vehicles (UAVs). This innovative new solution is the result of close collaboration between Klau Geomatics and Hexagon's Geosystems Division, enabling users to conduct UAV surveying projects without running a local GPS receiver, producing high-accuracy 3D survey data. In addition to accuracy, which is the most important feature, this georeferencing solution offers a simplified and efficient workflow. Users do not need any survey equipment to place ground control points (GCPs) or even a local base station for their PPK. They can collect precise georeferenced UAV data and even capture ground checkpoints just using their UAV, said Adam Chabok, technical director of Klau Geomatics. With the simplified plug-and-play payload, the system can be easily attached to any UAV or manned aircraft.

▸ **https://bit.ly/2tEZz3W**

Teaming up for Canada's Largest BVLOS Drone Trial

One of Canada's leading commercial drone operators, IN-FLIGHT Data, is embarking upon the country's largest beyond-visual-line-of-sight (BVLOS) UAS operations trial to date. It is receiving support from senseFly, the industry's leading provider of professional mapping drones and a commercial drone subsidiary of Parrot Group. The project's goal is to demonstrate that BVLOS UAS flights can be conducted safely and efficiently, while providing cost reductions and/or operational efficiencies for the different use cases involved. Chris Healy, the owner of IN-FLIGHT Data, said his team is excited to get the go-ahead for this ambitious project. Working closely with senseFly and the company's 20 partner organisations, they will be collecting a huge amount of geo-accurate data – across many types of long-range drone applications – which will help contribute to the creation of pragmatic future BVLOS legislation.

▸ **https://bit.ly/2N9kmVp**

Chris Healy, IN-FLIGHT Data, with a senseFly UAV.

5 Need-to-know Articles

Education is a key pillar of the mapping and surveying profession. At GIM International we do our very best to keep you informed with the latest knowledge, tailored to the demands of the geospatial industry's broad spectrum of interests and applications. This week, we are highlighting five articles providing need-to-know information for everyone involved with the aspects concerned: UAV photogrammetry software, spectral image cameras, the latest Lidar developments, the main challenges to consider when selecting a UAV for your mapping project and, last but not least, information about how to use the captured geospatial data effectively.

▸ **http://bit.ly/needtoknowgeo**

Increasing the Accuracy of Mobile Mapping Positioning Using SLAM

Mobile mapping systems usually rely on GNSS observations to maintain high positioning accuracy. Meanwhile, it is often necessary to use these systems to map areas where GNSS observations are not available, such as in tunnels, forests or urban areas with high buildings. Thus there is considerable interest in finding alternative sources of positioning data. The master's thesis on 'Increasing the Accuracy of Positioning in Mobile Mapping Systems' investigated how point clouds from laser scanning can be used to support positioning using simultaneous localisation and mapping (SLAM) technology. SLAM is the computational problem of finding a robot's position in an unknown area while mapping the area at the same time.

Mobile mapping systems are used to map the surroundings while on the move. One example is laser scanning of roads while driving in normal traffic. Mobile mapping can make data capture both safer and more efficient compared to traditional land surveying. The product is often a point cloud from laser scanning. Point clouds can be very detailed and are a perfect tool for further investigations and mapping of the terrain.

The accuracy of the point cloud depends on accurate positioning of the laser scanners. Positioning is often done by GNSS/INS-aided navigation. Inertial navigation has high accuracy over short periods, but tends to drift over time. Support from GNSS observations reduces the problem of drift, and high accuracy can be achieved for longer periods of time.

Lower accuracy is an issue whenever there are longer periods of GNSS outage. This is often solved by additional points ('known points'), captured by traditional land surveying. The point cloud from laser scanning can be 'matched' to fit the known points. Although matching can be done quite efficiently in software such as Terrasolid's TerraMatch, for instance, the entire process of land surveying and matching of point clouds is quite time-consuming and work-intensive.

The point cloud from laser scanning can also be used to obtain observations of relative movement, based on scans of the same object at two different points in time. This can be done either by passing the same object multiple times or by scanners mounted so that the same object is scanned multiple times with a small time difference in between due to the vehicle's motion.

SLAM can be used to take advantage of observations from the point cloud to support navigation. In the thesis, this approach was tested in post-processing using the TerraPos and TerraMatch software solutions, as well as additional software developed to integrate them. TerraMatch was used to automatically find relative point cloud observations. TerraPos is a navigation processing software with support for SLAM and was used to process navigation using relative point cloud observations to support the inertial navigation.

Tests done in the thesis showed that using point cloud observations in navigation processing can increase the accuracy of positioning in areas without GNSS observations, which in turn gives higher accuracy of the point cloud. This has the potential to reduce the need for additional land-surveyed points and can make the entire process of mapping by mobile systems less time-consuming and work-intensive. More testing is needed to evaluate the method for different terrain types and mobile mapping systems.

▲ *Marianne Løvås.*

Using more of the data collected by the mobile mapping system can make the navigation processing more robust and make it possible to provide high accuracy in a wider range of terrain types. It is a matter of taking advantage of as many available sensors for navigation as possible. ◀

ABOUT THE AUTHOR

Marianne Løvås completed her thesis about the use of SLAM in mobile mapping for her master's degree in geomatics at the Norwegian University of Science and Technology in 2017. Since then she has been working with mobile mapping at TerraTec AS.

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INTERVIEW WITH MAXIMILIAN BOOSFELD, CEO, WINGTRA

Setting a New Standard in **UAV Precision Mapping**

Switzerland-based start-up Wingtra has developed a vertical-take-off-and-landing (VTOL) unmanned aerial vehicle (UAV or 'drone') that rises straight up, tilts and flies off like an aeroplane. The WingtraOne is a broad-coverage drone that is used particularly in the surveying, construction and precision agriculture industries and which can capture images in photogrammetric resolution. Offering high-precision mapping in combination with the VTOL and post-processed kinematic (PPK) capabilities, the manufacturer believes it has a strong advantage over the other aerial surveying solutions currently on the market. *GIM International* decided to talk to Maximilian Boosfeld, co-founder and CEO of Wingtra, to see where the Swiss company is heading.

Wingtra was founded in 2016 as a spin-off of the Autonomous Systems Lab at ETH Zurich. Can you tell us more about the early days?

The story of Wingtra started with an ambitious research project called Pacflyer which Basil Weibel, our current chief revenue officer (CRO), and Sebastian Verling, now senior software engineer, were working on at Prof Dr Roland Siegwart's Autonomous Systems Lab. The aim of the project was to build a new-generation drone that would overcome the limitations faced by current drone solutions. Basil and Sebastian along with the other two founders of Wingtra – Elias Kleimann and myself – shared an idea of making a global positive impact. Therefore, when the initial research was over, we decided to join forces and make the idea come alive. We wanted our drone to carry the most valuable goods on Earth, and realised that aerial information has the best value-to-weight ratio. This epiphany was the motivation behind assembling the team and creating Wingtra.

How would you describe your company today?

Wingtra has grown to become an international company with distribution partners on every continent (except Antarctica). Our customers have completed more than a thousand flights and the interest in the industry is continuing to increase at a rapid pace. I believe we are very much on track to fulfil our initial goal of delivering high-accuracy data robustly and efficiently. Today, our WingtraOne drone collects thousands of gigabytes of aerial data and is used by mapping professionals in applications that range from surveying and mining to wildlife monitoring.

What distinguishes Wingtra from other UAV companies within the mapping and surveying industry?

WingtraOne is the first VTOL drone to be equipped with professional photogrammetry sensors. I also feel confident enough to say that, currently, we are the largest commercial VTOL player in the surveying, construction and precision agriculture industries. The VTOL advantage is threefold. Firstly, vertical take-off and landing means our users can reach previously 'unsurveyable' areas; one of our customers in Australia, for example, operates the WingtraOne from a boat. This helps them pursue their research in wildlife monitoring of a vulnerable sea mammal, the dugong. Secondly, the sensors are always protected – unlike the case of belly landings that fixed wings have to resort to. We can

equip our drone with ultra-high-accuracy sensors without the fear of damage, which helps us achieve unprecedented aerial accuracy in the sub-centimetre range. Thirdly, VTOL ensures a completely hands-off experience for our users. They can focus on data acquisition, without having to worry about drone operation.

Strictly speaking, a drone is just a device. Which range of payloads are you offering to mapping and surveying professionals?
WingtraOne is a device enabling what was not possible before, namely photogrammetric resolution with a broad-coverage drone. When it comes to RGB cameras, for surveying professionals looking for ultra high precision, we offer the Sony RX1RII: a full-frame 42MP camera. This payload can also be bundled with our PPK upgrade for ultra-precise mapping (accuracy down to 1cm) without the use of ground control points. For surveyors looking for an entry-level bundle or 3D reconstruction, we offer the Sony QX1 Pro, and Sony QX1 Pro with a 15mm lens, respectively. Besides these RGB cameras, we offer the Micasense Rededge M to professionals looking for an advanced solution for precision farming and plant analysis. FLIR Duo Pro for thermal mapping and monitoring is coming soon. Crucially, the WingtraOne has been designed to be completely modular, so any of the payloads can be swapped for the other in no time!

Can you explain more about the software aspect of the data acquisition?
The WingtraOne drone is operated through the intuitive flight planning app called WingtraPilot. WingtraPilot includes various ways to plan missions, monitor and revise them during the flights and inspect the data output while out in the field. We designed WingtraPilot to maximise successful aerial data acquisition. Before the flight, WingtraPilot runs background checks like battery health, GPS reception and imaging to make sure that everything is in order for the mission. It also guides the operator through the pre-flight process and catches oversights.

▲ *The WingtraOne VTOL drone.*

We like to joke that WingtraPilot is so easy to use that even a child could operate the drone!

Mapping generates a massive amount of data. What about the challenge of processing all the data?
We live in a data-driven society where data storage is becoming cheaper while computational power keeps increasing. Cloud solutions especially are becoming more robust, which makes me think they are likely to become the future of data processing. In the mapping industry, several post-processing solutions already make use of this. Last year we partnered with Pix4D to deliver a full mapping drone combo – a drone to ensure the smoothest data collection and the software which turns the data into actionable insights.

Aerial mapping is not limited to photogrammetry. What are your thoughts on UAV-Lidar mapping, and can we expect any movement in this direction from your side?
Lidar mapping could definitely be an option for the future. However, with the recent launch of the WingtraOne PPK drone, we are keen to focus on our current and prospective users and are keeping our eyes and ears open for all the feedback they have.

What is the secret behind ETH Zurich – and Switzerland in general – in terms of generating so many successful start-ups in the geospatial business?
For one, Switzerland has a long history of innovation in high-precision technology – after all, it's the land of the watchmakers! Another way to look at it is that the beautiful mountain landscape that makes Switzerland famous has also presented big challenges for the geospatial business. Engineering achievements such as the Gotthard Tunnel are world famous. In fact, WingtraOne itself was used in projects like mapping of the Alpine region for building wind farms and terrace farming locations near Lake Biel where vineyards are cultivated.

The second piece of puzzle in terms of the impact of aerial solutions for geospatial applications comes from the large talent pool concentrated at ETH Zurich and EPFL, both world-famous universities that attract

THE BEAUTIFUL MOUNTAIN LANDSCAPE THAT MAKES SWITZERLAND FAMOUS HAS ALSO PRESENTED BIG CHALLENGES FOR THE GEOSPATIAL BUSINESS

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intelligent and passionate engineers from around the globe. ETH Zurich's history in control and robotics has given rise to many start-ups and innovative organisations, such as PX4 which can be considered the gold standard for open-source software for drones.

Your company recently appointed Cyril Halter – former COO and co-founder of what could be seen as one of your competitors, senseFly – to take over your role as COO. What's the strategy behind that decision?
Our strategy is the launch of the high-precision drone WingtraOne PPK. The Wingtra team expects it to become the most desired drone in high-precision surveying and mapping applications. Cyril Halter is exactly the person we need to help us reach this goal. He will focus on the industrialisation and the ramp-up of production. His tremendous industry experience will definitely be put to good use at Wingtra.

Zooming in on the future of drones for geospatial applications, how do you think new developments such as artificial intelligence (AI) and machine learning will influence aerial mapping?
We're already seeing the use of machine learning kicking in for environmental and research applications. Take our customers from Murdoch University in Australia, for example, who are operating WingtraOne from a boat to collect aerial images of a vast area of ocean for their wildlife research project. They are using machine learning algorithms to count sea mammals in the water, monitor their behaviour and ensure better protection of endangered species.

The other implication of machine learning for geospatial applications is likely to be in the field of computer vision. We're seeing this already in the case of orthomosaic generation (map stitching) software that not just matches individual pictures from the collected dataset, but also corrects camera orientation. This leads to higher accuracy in mapping. Besides this, we can perhaps expect improvements in the arena of dynamic obstacle avoidance using vision, or more robust localisation in the case of GPS loss. However, these improvements are still limited by the low computational power and memory offered by current embedded devices, which need to stay small and lightweight for UAVs.

What are your thoughts on the legislation and regulations for commercial drone use?
I believe that the latest regulatory developments have mainly had a positive effect on our business. Rules are converging and this helps our professional customers to reduce planning uncertainty. Many of the regulations are aimed at respecting the enormous potential of commercial drone use for the economy while still making flying safer. Privacy is the other hot topic in drone regulations, but this applies much more to recreational drones and their operators and is less of an issue in the professional surveying segment.

Which other developments do you expect to have a major influence on UAV mapping in the years ahead?
At Wingtra we strongly believe that the VTOL technology will be the one to disrupt the industry. After all, Wingtra was founded based on high ambitions to overcome those limitations. With ever-more sophisticated VTOL technologies, the gap between fixed wings and multirotors should slowly disappear which will rapidly broaden the application scenarios. Besides that I believe that much more powerful batteries will be developed, breaking the limits of imagination regarding what can be achieved with drones during long missions. ◂

More Information
www.wingtra.com

ABOUT MAXIMILIAN BOOSFELD

Maximilian Boosfeld is co-founder and CEO of Wingtra, a manufacturer of high-precision VTOL drones that collect survey-grade aerial data. From the very start, Maximilian has helped Wingtra to become an international company with distribution partners across the globe and supplier of the very first VTOL drone to be equipped with professional aerial photography sensors. Prior to Wingtra, Maximilian studied mechanical engineering at ETH Zurich and in parallel ran his very first successful company: the open-air café called 'Kleine Freiheit'.

THE PROMISING FUTURE OF MOBILE MAPPING AND LASER SCANNING

Mobile Lidar Systems Today and Tomorrow

Mobile Lidar systems (MLSs) are used with increasing frequency for three-dimensional (3D) mapping applications along various corridors because of their extreme ease in capturing high-resolution 3D topographic data. This article examines the current state of the mobile Lidar system market before looking ahead to the future scope for mobile mapping and laser scanning, including potential challenges that lie ahead.

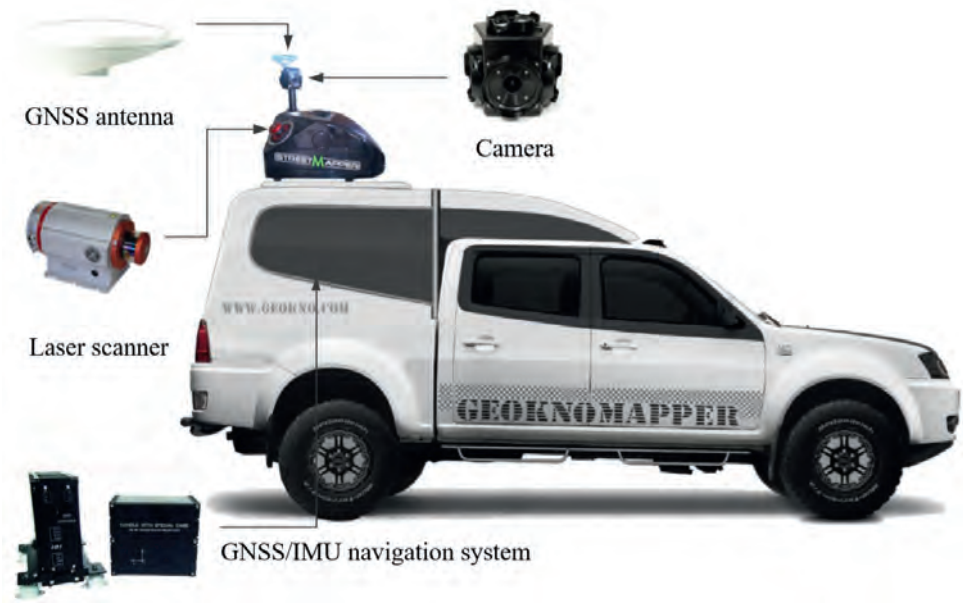
Mobile Lidar systems are frequently used for 3D mapping applications along various corridors because of their extreme ease in capturing comprehensive high-resolution 3D topographic data at normal speeds. An MLS observes a corridor and nearby objects in the form of their dense coordinates, leading to creation of a detailed 3D model of the corridor environment. Considering data quality and the completeness of the information captured by an MLS, it surpasses the traditional methods of data collection along corridors. Due to high accuracy and extensive information content in data, MLSs are being used along various corridors for topographic data collection, e.g. highways, railways, waterways, city streets, etc. The data is then used for solving various problems associated with these corridors, e.g. mapping roadside assets, assessing the condition of road surfaces, assessing road geometry, generating detailed project reports for widening of existing corridors, etc.

An MLS offers several advantages over traditional corridor survey methods, including high-speed data capture (time and cost reduction), high density of collected point cloud so no detail is missed, comprehensive topographic survey, minimisation of erroneous/questionable data, remote acquisition and measurement (increases survey efficiency and safety), and deliverables being coloured in the 3D point cloud for accurate representation of the objects in a scene. Widespread and frequent use of MLSs by various agencies has resulted in lower survey costs than with the traditional techniques, which is also a reason for its adoption as a mainstream surveying method for corridors, especially highways.

EXISTING MOBILE LIDAR SYSTEMS

Over the past decade, numerous commercial MLSs have been developed by various manufacturers, e.g., RIEGL, Teledyne Optech, 3D Laser Mapping, Topcon, Renishaw, Trimble, Mitsubishi Electric, Leica Geosystems and Siteco Informatica. The latest multi-laser MLSs, such as the RIEGL VMX-2HA, StreetMapper IV, Trimble MX9 and Road-Scanner 4, offer more than 400 metres of roadside coverage. Laser range measurement accuracy to less than 6mm is mentioned in the datasheets of the RIEGL VMX-2HA, StreetMapper IV, Trimble MX9 and Leica Geosystems, while in the case of Lynx SG only range precision is given which is less than 6mm. Figure 1 shows a typical MLS and its components.

The orientation architecture of laser scanners is different in each MLS. For example, the RIEGL VMX-2HA, Lynx SG, StreetMapper IV, Dynascan S250, Trimble MX9 and Leica Pegasus:Two Ultimate are dual-head laser systems, while the IP-S3 HD1 and the MLS-G220ZL both have three laser heads and the Road-Scanner 4 is equipped with just



▲ Figure 1: StreetMapper MLS and its components.

Mobile mapping system		Laser scanner				IMU/GNSS	Absolute accuracy	Digital camera
Make	**Model**	**Sensor(s)**	**Range**	**Accuracy (A)/ Precision (P)**	**PFR**	**Positioning accuracy (absolute)**		**Resolution**
RIEGL	VMX-2HA	2, RIEGL VUX-1HA	Up to 420m @ p ≥80% and PFR =300kHz	A: 5mm @ 30m (1σ) P: 3mm @ 30m (1σ)	Up to 1MHz @ 235m range	Typ. 20-50mm (1σ)	NA	Options for up to 9 each 5,9,12MP CMOS, Nikon D810 (7360×4912px); FLIR Ladybug5+ (6×5MP)
Teledyne Optech	Lynx SG	2, Lidar sensors	Up to 250m @ p =10%	A: NA P: 5mm, 1σ	Up to 600kHz	NA	±5cm, 1σ @ 10m range and PDOP <4	Up to four 5MP cameras and one Ladybug camera
3D Laser Mapping	StreetMapperIV	1-2, RIEGL VUX 2D scanner	420m @ p =80%	A: 5mm P: 3mm	1000kHz	NA	NA	Ladybug5 6×5MP
Topcon	IP-S3 HD1	1, Velodyne scanner HDL-32E	Up to 100m @ p =100%	A: 2cm P: NA	700kHz	NA	50mm, 1σ @ 10m range and 10mm, 1σ on road surface	Six-lens digital camera system (8000×4000px)
Renishaw	Dynascan S250	1-2, Lidar sensor	250m	A: 1cm @ 50m (1σ) P: NA	36000	2 to 5cm	NA	…….
Trimble	MX9	2, laser scanners	Up to 420m, @ p ≥80% and PFR =300kHz	A: 5mm P: 3mm	Up to 1MHz @ 235m range	0.02–0.05m	NA	One Spherical camera, 30MP (6×x 5MP); two 5MP side-looking cameras; one 5MP backward/downward-looking camera
Mitsubishi Electric	MMS-G220/ MMS-G220ZL (option)	2, laser scanners; 1 additional long-range and high-density laser scanner (option)	65m; 119m (option)	A: NA P: NA	27.1KHz; 1MHz (option)	Within 6cm (RMS)	Within 10cm (RMS) @ 7m.	Two cameras, 5MP
Leica Geosystems	Leica Pegasus:Two Ultimate	ZF 9012	119m	A: 9 mm @ 50m and p =80% (1σ) P: NA	1.1MHz	NA	0.020m RMS Horizontal; 0.015m RMS Vertical	4 built-in cameras 12MP, optional 1 or 2 additional adjustable external cameras; 2 dual fish-eye cameras 24MP
		Leica ScanStation P20	Up to 120 m; 18% reflectivity	A: 3 mm at 50 m P: NA	1 MHz			
Siteco Informatica	Road-Scanner 4	Faro Focus 130/330	130m/330m @ p =90%	A: 2mm/2mm P: NA	976kHz/976kHz	NA	NA	Spherical Ladybug5 camera 30MP.
		Z+F 9012	119m	A: 9 mm @ 50m and p =80% (1σ) P: NA	1.1MHz			
		RIEGL VQ250/ VQ450	300m/700m @ p ≥80% and PFR = 200kHz	A: 10mm/8mm, @ 50m (1σ) P: 5 mm/5mm @ 50m (1σ)	Up to 300kHz/550kHz			

▲ *Table 1: System components of commercially available MLSs.*

one. Generally, these multi-laser-head MLSs are expensive (in excess of US$250,000), large in size and operator training is necessary. Table 1 shows a comparison of the commercially available and most commonly used systems.

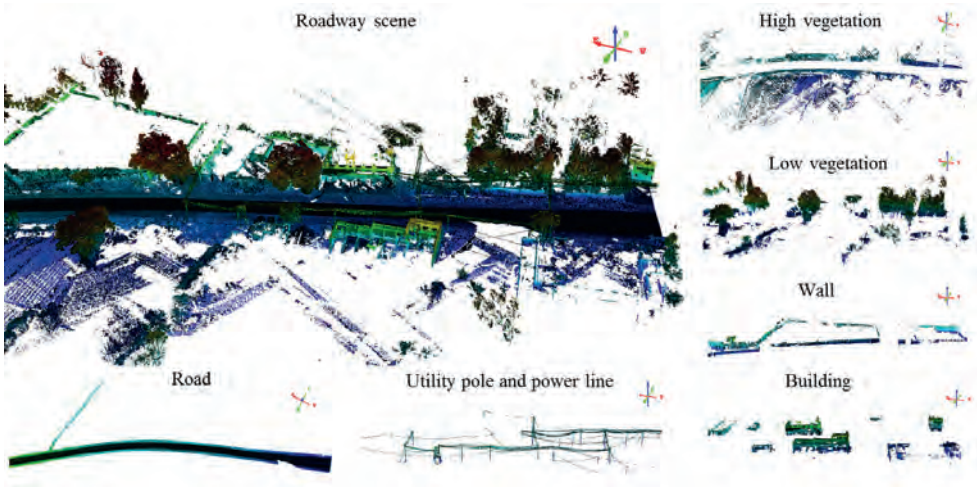
HARDWARE AND DATA PROCESSING

An MLS is an integrated assembly of ranging and imaging sensors with positioning and orientation systems. Rapidly advancing MLS hardware technology is improving the performance of MLSs. New, miniaturised sensor technology is leading to easier sensor integration and provides flexibility in mounting the sensors on different types of moving platforms. System miniaturisation opens up new avenues for more versatile and less expensive MLSs.

While the MLS hardware has improved multifold, the bottleneck in the adoption of technology has shifted from the data acquisition stage to the processing stage. The main problem in using MLSs is processing the vast quantity of data. Automation in feature extraction is only partially achieved, although researchers are continuously making efforts in this respect (Yadav et al. 2017 and 2018). MLS data processing for various applications is generally performed in three sequential steps: (1) removal of outliers, noise and unwanted information; (2) processing of filtered data for object extraction; and (3) modelling or generating a GIS database. Since the data acquired by an MLS is dense and volumetric, its processing demands intensive manual intervention. For example, a vehicle-based MLS operating at normal highway speed, e.g. 50km/h, can acquire around one gigabyte data for each kilometre, thus generating an excessive

amount of data which may require one full week of processing on one work station.

Keeping in mind these requirements, industry and academia are designing automatic data processing methods and software tools for accurate extraction of corridor information from MLS data (Figure 2). Automatic detection of corridor objects becomes difficult in the case of complex scenes and the unorganised nature of point data. Many semi-automatic methods are available for extraction of common features, e.g. in case of a highway, high and low vegetation, utility poles, power lines, wall and buildings. However, their applicability is limited to only well-structured and predictable MLS datasets.



▲ Figure 2: Perspective view of vehicle-based MLS data of a roadway scene and extracted features.

CHALLENGES AND FUTURE SCOPE

The fixed architecture of an MLS with a limited number of sensors and their fixed orientation on a rigid platform limits its performance as it does not provide the flexibility of operation which might be required for different applications. The available MLSs are often used on a specially designed platform, meaning that installation on a non-designated platform can be impractical, cumbersome and time-consuming. The laser pulses from side-looking laser scanners onboard an MLS generally hit a target at non-uniform spacing across the sensor path, which leads to different point densities across the area of interest. The viewing geometry of laser scanners is also responsible for data gaps due to occlusions. In dense traffic conditions on a highway, for example, the data acquired by a vehicle-based MLS is incomplete and several important pieces of information may be omitted due to occlusions. Currently such data gaps are partially avoided either by conducting the survey in quieter traffic conditions or by conducting multiple drives of the MLS, but this increases the survey costs. Due to the data gaps caused by non-uniform spacing, occlusions and complex scene geometry, automatic segmentation and classification of corridor objects become tedious tasks. Further, in order to generate good absolute accuracy of data, a large number of ground control points are required.

The miniaturisation of sensors helps to solve the problem of rigidity in the sensor integration and mounting architecture, but extensive work still needs to be done in terms of optimal application-oriented sensor layout design. The future may see new sensor integration architectures to facilitate easy installation and calibration on variable platforms so as to collect the data required for different applications. Plug-and-play system architecture would help operators in the field to design their own systems as per their requirements. The advances in multi-sensor integration will be seen in the near future for high-end mapping applications, where Lidar and visual simultaneous localisation and mapping concepts from robotics and computer vision technology can be used for image-based georeferencing. This will facilitate mobile 3D data capture and the updating of existing digital 3D realities using small, lightweight and inexpensive devices. Minimising manual intervention and designing automatic feature extraction techniques for 3D point clouds of complex corridor scenes is an important need. It will be interesting to see the developments in the use of deep learning for data classification (as in Kumar, et al., 2018). ◀

THE ADVANCES IN MULTI-SENSOR INTEGRATION WILL BE SEEN IN THE NEAR FUTURE FOR HIGH-END MAPPING APPLICATIONS

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DATA ANALYSIS BY GEOMARES

Mobile Mapping Trends and Insights

Mobile mapping technology is on the rise worldwide. Industry specialist Geomares – publisher of *GIM International* among other things – has analysed the user data and behaviour of thousands of members of the global geospatial community. This article presents the findings from that analysis, identifying the latest trends and sharing insights into the future outlook for mobile mapping.

Recent advances in mobile mapping technology are enabling new capabilities and complementing – or even replacing – traditional survey methods of topographical surveying. Futhermore, widespread investment in city planning and 'smart city' projects is expected to further accelerate the adoption of mobile mapping technology worldwide. 450,000 geomatics professionals visited the *GIM International* and/or Geo-matching websites in 2017, and a large percentage of those online visitors were interested in mobile mapping systems. This puts Geomares in a unique position to analyse website behaviour to discover trends and insights related to mobile mapping systems. To provide a balanced overview, this analysis is based on a combination of Geo-matching website data, the *GIM International* readers' survey, Google search statistics and market research.

5 IMPORTANT CONSIDERATIONS WHEN PURCHASING A MOBILE MAPPING SYSTEM

1. Application – Type of Mobile Mapper

The application is a very important consideration for purchasing a mobile mapping system. If you want to map outdoor terrain (e.g. a mine or a highway) a vehicle-mounted mobile mapping system is usually most suitable. If you plan to map indoor environments (e.g. rooms, corridors, production locations) a portable and indoor mobile mapper may be more suitable.

2. Photogrammetric or Lidar Camera

Photogrammetry or Lidar point clouds? Both have their advantages, and the most suitable one depends on the particular application. There is one key difference that distinguishes photogrammetry from Lidar, namely RGB. Photogrammetric point clouds have an RGB value for each point, resulting in a colourised point cloud. On the other hand, when it comes to accuracy Lidar is hard to beat. But not all projects require the same accuracy, which is why it is always good to do some research first before you decide which method works best for you.

3. Processing Software

In the article called 'Comparing Lidar and Photogrammetric Point Clouds', which appeared in *GIM International's* January/February 2018 issue, point clouds are compared for inspecting a flood control structure. In this scenario, Lidar output takes far less time to process and provides a clean and sharp point cloud that is easy to work with. The photogrammetric data collection and processing took slightly longer and the point cloud required extensive cleaning.

4. GNSS/INS Positioning System

Operating in buildings, tunnels and mines requires advanced solutions since there is no GNSS coverage. This is important to consider when choosing a GNSS/INS system for your mobile mapper.

5. Compatibility

The ongoing miniaturisation of sensors and electronics has led to the construction of laser scanners which are light enough to be mounted on an unmanned aerial system (UAS), trolley, backpack or stick. Some mobile mapping systems are compatible with a variety of applications from multiple systems (UAS, backpack, car, etc.).

BEHAVIOUR OF GEO-MATCHING USERS

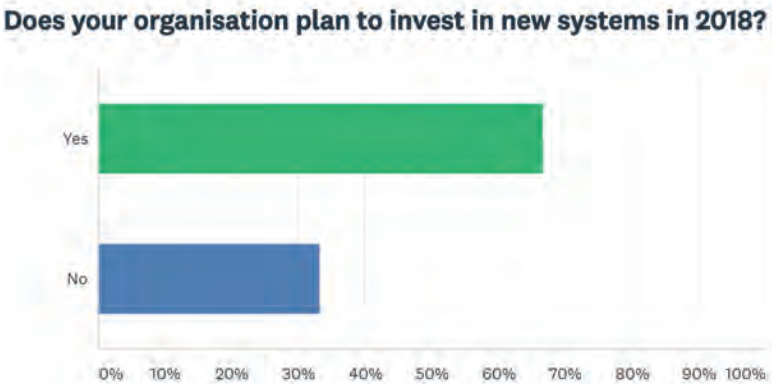
Data from the Geo-matching website shows strong growth in interest in mobile mappers. Geo-matching is the world's largest product platform for surveying, positioning and machine guidance, listing more than 2,000 products from 500 manufacturers and attracting more than 250,000 users in 2017. Mobile mapping technology is one of Geo-matching's most important sections, featuring 52 products from 25 manufacturers. In mid-2017 and 2018, Geo-matching started paying extra special attention to mobile mapping systems, with direct success. Since September 2017 the number of page views has more than doubled (see Figure 1). This shows that there is a strong interest in mobile mapping systems. In June 2018 more than 3,300 mobile mapping pages were viewed – an absolute record.

READERS' SURVEY DATA

GIM International regularly surveys its readers on a number of topics, and the latest survey was conducted in December 2017 (615 respondents). 67% of the respondents indicated plans to invest in new systems in 2018 (Figure 2).

GIM International also asked its readers which type of systems they plan to invest in. 20% of the respondents plan to invest in mobile

▲ *Figure 1: Views of Mobile Mapping pages on Geo-matching.*



▲ *Figure 2: Findings from* GIM International *Readers' Survey 2017.*

mapping systems and/or portable and indoor mobile mapping systems. These results are a strong signal that geospatial professionals are considering the purchase of mobile mapping systems, and that level of demand is expected to rise further in 2018 and beyond.
Another question asked which trends geospatial professionals foresee in their industry over the next five years. The increasing role of mobile mapping systems is one of the most striking outcomes that can be derived from the survey results. Mobile mapping systems also go hand in hand with the need for more accurate 3D city models, as mentioned by some respondents.

GOOGLE SEARCH STATISTICS

Google Keyword Planner was used to study the search volume for mobile mappers worldwide (see Figure 3) from 2014-2018. Google statistics show that a strong increase in the search volume for mobile mappers. In 2016 there were on average 9,000 searches per month, compared with 7,000 in 2014. The average for 2018 currently stands at about 14,000 searches per month, representing an especially steep growth (of approximately 65%) in search volume from 2016 to 2018. These figures include searches for mobile mappers and similar terms such as mobile laser scanning, mobile mapping system, indoor mobile mapping and so on, but do not include specific brand or product names.

GEO-MATCHING PROFILE OF TYPICAL MOBILE MAPPING USERS

Since 2012 thousands of geospatial professionals have used Geo-matching to contact manufacturers directly. This gives Geo-matching a unique insight in the user types looking for mobile mapping technology. In 2015 Geo-matching included just 16 mobile mapping systems, whereas it now features 52 – an increase of 325% in the space of three years.
Geo-matching has seen enquiries ranging from major organisations like NASA and the US Army of Engineers to surveying companies of all shapes and sizes worldwide. Enquiries have also come from infrastructure companies (e.g. road survey, corridor mapping, etc.), maritime companies (monitoring of harbour walls), forensics (crime mapping and traffic accident investigation), mining (open-pit survey, etc.) and even some surprising sources such as New York City's Metropolitan Opera House (indoor mapping for maintenance and monitoring purposes).
In 2015, 36 enquiries were made through Geo-matching, rising to 52 enquiries in 2016 and 132 in 2017 (Figure 4): a 250% increase from 2016 to 2017. The growing number of enquiries made on Geo-matching is a clear sign that mobile mapping applications are incredibly diverse and that new potential customers have entered the market in recent years. Geomares attributes this increase to greater general interest in mobile mapping systems, Geo-matching's stronger focus on the topic of mobile mapping and the fact that there are more mobile mapping systems listed on Geo-matching.

REGIONAL DISTRIBUTION

Although mobile mapping technology is used worldwide, 50% of all users looking for mobile mapping technology on Geo-matching are from the Asia-Pacific region (see Figure 5). This is an interesting finding that is supported by other market research stating that increased investment to develop infrastructure in Asia-Pacific – the need for which is created by the process of hyper-urbanisation that is currently underway

TYPES OF MOBILE MAPPING SYSTEMS

Mobile Mappers

When thinking about mobile mapping, most people probably associate it with vehicle-mounted systems or 'mobile mappers'. These devices that collect geospatial data from a mobile vehicle, typically fitted with a range of photographic, radar, Lidar or any number of remote sensing systems. Such systems are composed of an integrated array of time-synchronised navigation sensors and imaging sensors mounted on a mobile platform and used for outdoor applications. The increasing demand for 3D maps of cities and road networks and the need for up-to-date 3D models form the key pillars of the expected growth of the global mobile mapping market.

▲ *Image 1: Teledyne Optech Lynx SG mobile mapper.*

Portable and Indoor Mobile Mappers

Portable and indoor mobile mappers have entered the market over the past few years. The indoor counterparts of mobile mappers, portable and indoor mobile mappers fit in a backpack or are a compact mobile device. They scan indoor environments with either cameras or laser scanners. Datasets are georeferenced and point clouds can be coloured using cameras or laser scanners. Portable and indoor mapping solutions are applied to obtain accurate representations of 3D interiors in infrastructure such as underground mines and tunnels, plants and factories, airports, shopping malls, etc.

▲ *Image 2: Vexcel Imaging Panther.*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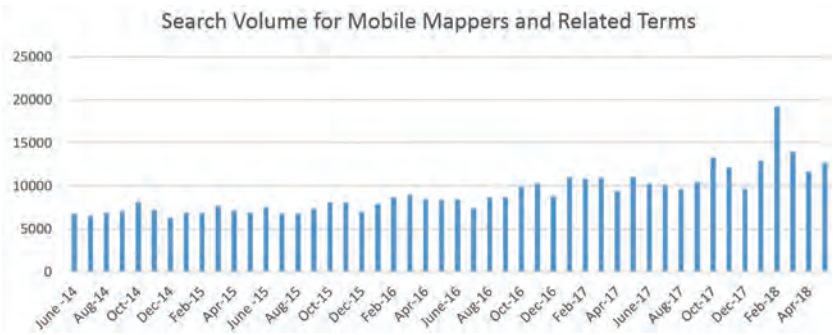
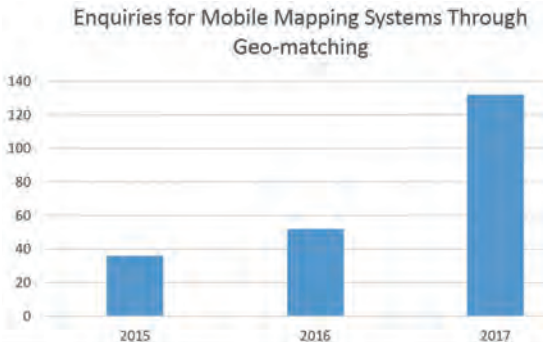


▲ *Figure 3: Google search volume for 'mobile mappers' and related terms. NB: The peak in February 2018 is due to a* National Geographic *article about a Lidar survey of ancient Maya structures in Guatemala.*



▲ *Figure 4: Number of enquiries through Geo-matching from 2015 to 2017.*

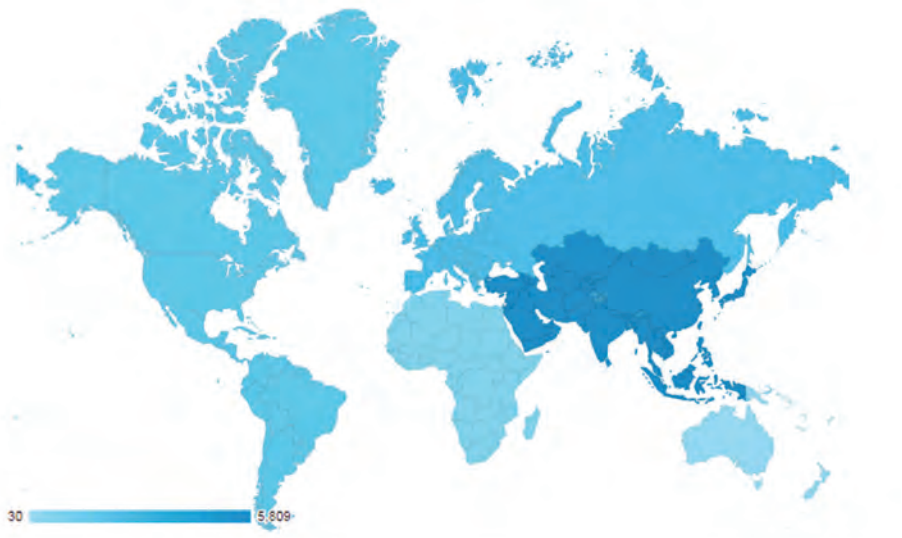
across the region – will boost demand for mobile mapping technology. As mentioned in the highly recommended article called 'Mobile Laser Scanning Point Clouds', published by *GIM International* in 2017, "the demand for 3D maps of cities and road networks is steadily increasing and mobile mapping systems are often the preferred geodata acquisition method for capturing such scenes". This is exactly what is going on in the Asia-Pacific region right now.

CONCLUSION

Geo-matching website data, the *GIM International* readers' survey, Google search statistics and market research all show clearly that the demand for mobile mapping technology has increased over recent years. Based on the findings from the readers' survey and other market research reports, it is safe to say that geospatial professionals worldwide will increase their investments in mobile technology in the coming years. The value of the global mobile mapping market is expected to reach US$32 billion by 2023 at an average growth rate of 21.3% per year. Substantial growth can be anticipated in North America and Europe because of the high potential of organisations that can implement mobile mapping technology and the large number of mobile mapping service providers. Market research anticipates, however, that the Asia-Pacific region will grow the fastest, with India, Japan and China leading the way. This is attributed to increased investment for developing infrastructure, which includes city planning and smart city projects.

50% of all mobile mapping pages on Geo-matching are viewed by visitors from the Asia-Pacific region. This shows that there is a strong interest in mobile mapping technology in that region and is consistent with the above-mentioned market research.

This article is based on the combination of content from various sources to provide general trends and insights related to mobile mapping. For more research data, reader survey details and/or a personalised report, please contact Sybout Wijma (sybout.wijma@geomares.nl). ◀



▲ *Figure 5: Regional distribution of Geo-matching users looking for mobile mappers.*

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5. *GIM International*: 'Mobile Mapping' by Mathias Lemmens (See Editorial Note 'Mobile Mapping', page 6 of this issue)

MORE INFORMATION

www.geo-matching.com

ABOUT THE AUTHOR

Peter Tapken is content manager for Geo-matching – a leading product platform for surveying, positioning and machine guidance. He is responsible for the website content, product development and online marketing. He has a background in marketing management, having completed his Master of Business Administration at the University of Groningen and also gained a BBA in Mangement, Economics and Law from Saxion University of Applied Sciences in Enschede, both in The Netherlands.
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IMPROVING RAIL INFRASTRUCTURE INSPECTION EFFICIENCY WITH ENHANCED DRONE PLATFORM

Aerial Data Acquisition for a **Digital Railway**

One of the major challenges facing railway networks is preventing failures in railway tracks. Avoiding potential track malfunctions means inspecting thousands of miles of track, while avoiding risk to inspectors and traffic interference. One innovative inspection methodology is to build a 'digital railway' – an accurate and dynamic visualisation tool to identify actual and potential track damage. Relying on the highest-quality data acquisition, a digital railway helps those responsible to make better informed decisions while planning and prioritising rail development, maintenance, repairs and renewal projects. This article outlines the use of such a tool in a UK railway project.

In collaboration with the UK's Network Rail, Plowman Craven recently developed Vogel R3D. This service, based on an unmanned aerial vehicle (UAV or 'drone'), facilitates the 3D measurement of rail infrastructure to sub-5mm accuracy. The tool was developed to conduct a comprehensive survey of rail infrastructure, offering aerial access to difficult-to-reach areas and limiting risk to ground-based personnel. High-resolution images enable the survey to capture a larger surface area in a single flight. Once captured, overlapping images are processed in photogrammetry software to produce an accurate 3D point cloud. The software's pixel matching algorithms are used to solve the interior orientation parameters and aerial triangulation.

NEW UAV PLATFORM

The Vogel R3D system comprises an Aerialtronics drone, known for its safety and reliability, integrated with a Phase One Industrial 100 megapixel medium-format aerial camera. The lightest weight in its category, this camera's sensor is able to capture greater amounts of light for optimal data quality and has a high dynamic range to enable accurate measurement of both high and low-intensity objects within the same image.

One of the main attributes of the system contributing to the safety case is the aircraft's rotor setup. A total of eight rotors provide sufficient redundancy if one were to fail, whereas a motor failure on an aircraft with just four rotors would almost certainly lead to that aircraft crashing onto the tracks.

It is therefore clear why redundancy and reliability are critical to safety in this kind of operating environment. The safety features, hardware redundancy and track record of the Aerialtronics platform have enabled Plowman Craven to obtain an 'Operation Safety Case' from the Civil Aviation Authority, permitting the flying of the UAV in congested urban areas. These enhanced flying permissions are granted only to a handful of operators.

The sheer number of moving and parked

▲ *The Vogel R3D system comprises an Aerialtronics drone.*

▲ *Unlike with traditional methods of conducting railway surveys, topographical survey CAD data is complemented by ultra-high-resolution orthophotos and highly detailed coloured point clouds as well as the RAW photography.*

▲ *A successful survey was completed with the Vogel R3D at Guildford in Surrey, one of the busiest stretches on the British railway network.*

trains at some locations proves a constant challenge for the survey teams. A track can only be perfectly viewed when it is clear, meaning high levels of planning and preparation are required – particularly at busy stations where the track is unobstructed for only 60 seconds between train movements. Having the ability to manually pause surveying mid-flight until the train has passed is invaluable in this regard. In the system used, it is possible to set the photogrammetry overlap to ensure trains blocking tracks do not impact on the outputs.

ULTRA-HIGH-RESOLUTION IMAGERY ACQUISITION

Operating at a height of 35m, the Vogel R3D system follows a series of pre-programmed flight paths to capture thousands of overlapping high-resolution images. This ultra-high-resolution imagery is critical in the generation of high-accuracy survey-grade data and provides a complete visual record of the site as well as the measurement data. The high quality of the 100MP RAW photography captured enables the identification of even the smallest features. With ground sample distances of 1-2mm it is possible to identify markings on the sleepers and specific rail clips, as well as the location of flash butt welds. These are objects that are highly problematic for surveyors to visually locate when working on the tracks at night, equipped with just a head torch. Typically, a single UAV flight lasts around 10 minutes before a battery change is required, and approximately 300 images are captured during this time. Each individual flight is preceded by many safety checks covering both the integrity of the UAV system and any hazards within the area of operation. In its first six months working on the UK's railways, the Vogel system completed more than 50 flying hours across a range of projects, capturing more than 8TB of RAW photography.

DIGITAL RAILWAY VISUALISATION

Unlike with traditional methods of conducting railway surveys, topographical survey CAD data is complemented by ultra-high-resolution orthophotos and highly detailed coloured point clouds as well as the RAW photography. All this data can be provided in hard copy, as well as on Plowman Craven's cloud-based data management platform to enable access for multiple stakeholders. The ultimate value of this visualised data is highly significant. It enables stakeholders anywhere in the world to 'walk' through a specific site using a tablet or computer, allowing for imagery interrogation and measurement extraction. For train operators and maintenance companies with extremely limited information on the physical characteristics of their routes, being able to access such usable, verified survey data is hugely beneficial and supports decision-making when monitoring, planning, predicting and preparing future railway maintenance projects.

The advantages over traditional surveys are very clear. A successful survey was completed with the Vogel R3D at Guildford in Surrey, one of the busiest stretches on the network with more than 30 trains an hour passing through. Furthermore, with three branch lines converging at Guildford Station, gaining possession of all three at the same time would not have been possible, but Vogel eliminated the need for possessions and shaved several months and significant costs off the programme. The UAV was able to survey a 1,200m stretch of track, up to eight tracks wide, in just five days and with no track access required at all. Health and safety benefits aside, the client received the full topographical survey of all permanent-way (P-Way) detail, point cloud and orthophotos in a matter of weeks. Lineside and platform gauging was also conducted. ◀

FURTHER READING

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ABOUT THE AUTHOR

James Dunthorne is the UAV technical manager for Plowman Craven, one of the leading consultancy and surveying companies in the UK. He manages all UAV technical matters within the company and helps in the development and support of new products and services. James is also standards director for ARPAS and sits on the BSI committee for UAV standards in the UK. He works with major stakeholders and government to help develop the skies of the future.

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BY **DERRICK KOOME**, **CLEMENT OGAJA** AND **ELDAR RUBINOV**, CORSMAP

A TRUE REFLECTION OF INTERNATIONAL COOPERATION BETWEEN GEOSPATIAL PROFESSIONALS

Developing a **Fully Fledged CORS Map** for Africa

Continuously operating reference stations (CORS) are permanent GNSS stations that log and disseminate GNSS observations continuously to meet various user needs. CORS networks have been going up all over the world in the last decade to help establish geodetic reference frames, monitor tectonic movement as well as helping surveyors to do real-time positioning. This article zooms in on Corsmap, an initiative that was founded by three geomatic professionals to be a one-stop shop for all CORS installations in Africa.

There are many online maps that provide information about CORS networks in Europe, North America and the Australasian region. For instance the US National Geodetic Survey maintains a CORS map of all the permanent GNSS stations in North America and a few other selected countries. When it comes to Africa, however, the situation is vastly different. Some information is available from the International GNSS Service (IGS), the African Geodetic Reference Frame (AFREF) and Space and Earth Geodetic Analysis Laboratory (SEGAL) maps, but these maps are mainly focused on scientific applications and, as such, do not provide a full picture of what is out there. Moreover, there is a deplorable dearth of metadata concerning CORS installations. Most of the time it is simply a point on the map. It is difficult to find a single database that offers information about all the CORS installations in Africa. It is an uphill task to begin with to have such a database given the vast number of private, public or institutional CORS providers. However, a centralised database is paramount so as to avoid a patchwork of online maps of these key installations.

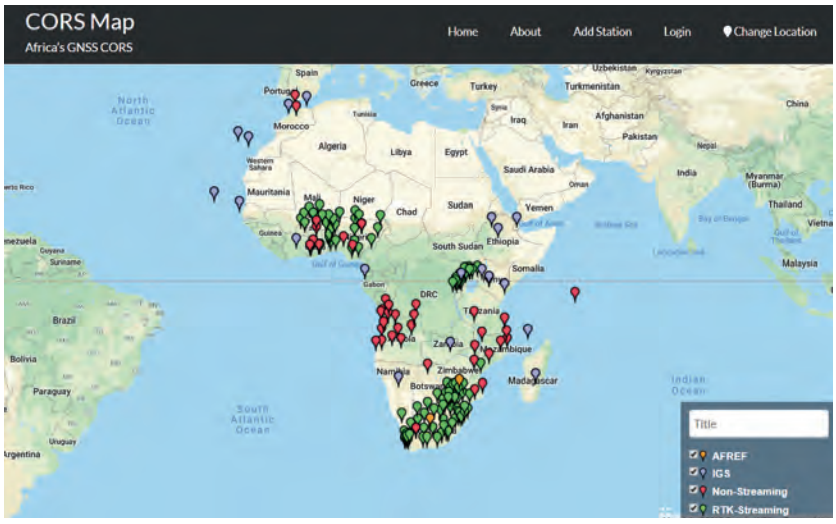
CROWDSOURCING

Crowdsourcing could be a powerful tool towards this end. This is what the founders of Corsmap are trying to achieve by mapping all the CORS installations on the African continent. Corsmap is not just about providing information about all the permanent GNSS stations in Africa; it is also about enriching the experience by giving the user as much information as possible concerning a particular GNSS installation.

Some of the Corsmap features include:

- Numerous ways of discovering station information quickly, such as pinpointing a location with a cursor or searching by keywords
- Easy and simple ways to add or edit station information for users
- Ensuring a lot of metadata is displayed once a location has been pinpointed (e.g. base station provider contacts, website, information on RTK and RINEX, photo of the base station and its background, etc.)
- A station detail page giving a brief introduction about a particular base station
- Zoomable pinpoint locations which can be zoomed to street level
- A community forum which enables users to register and add station information.

Whilst providing a lot of metadata, what the map does not provide is coordinates of the



stations and access to the data. Instead, the map points the user to the base station provider, where this information can be obtained.

So far, Corsmap has been able to crowdsource data for 180 CORS installations in 25 countries including South Africa, Angola, Mozambique, Rwanda, Uganda, Kenya, Ghana, Nigeria, Benin, Burkina Faso and more. However, contacts have only been made with custodians in four of these countries, namely South Africa, Ghana, Mozambique and Uganda. This means that the information from the other 21 countries has been sourced by the Corsmap founders themselves from other online maps and RINEX repositories, but the information has not been verified and controlled by the people on the ground. The Corsmap team is keen to encourage all African countries to provide the missing or unverified CORS information to help them update the map for the public good. Many countries such as Botswana, Namibia, Egypt, Tunisia, Algeria, Ethiopia and Ivory Coast remain unmapped. In some cases the language barrier poses a problem, although most of the time the lack of response from contacts seems to be the biggest challenge.

FAIR SHARE OF LEMONS

Populating Corsmap has not been an easy task. The founders have faced a lot of challenges: many e-mails have gone unanswered, many calls not taken, many LinkedIn requests ignored, but the few positive responses have been worth every effort by the Corsmap team. It has been a stark reminder that good things come with their fair share of lemons.
Despite the lemons which have been used to make lemonade, there have been some amusing moments as well, such as one user who claimed to have base station information for a particular country, only for him to provide the team with a link to their own Corsmap website. This particular incident was not only comical, but also reaffirmed the dearth of CORS base station installations in Africa.

UPLOADING THE BASE STATION DATA

Since the base station data as currently constituted has been obtained by the founders themselves, there is an undisputed need for maintenance and keeping the information current and relevant. Corsmap therefore depends on a network of trustworthy and reliable people to critique the information already provided. Data integrity is

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Eldar Rubinov received a PhD in GNSS from the University of Melbourne, Australia. He has held various positions as a hydrographic surveyor, researcher and GNSS entrepreneur. He is currently working as a technical manager on the Australian and New Zealand SBAS testbed.
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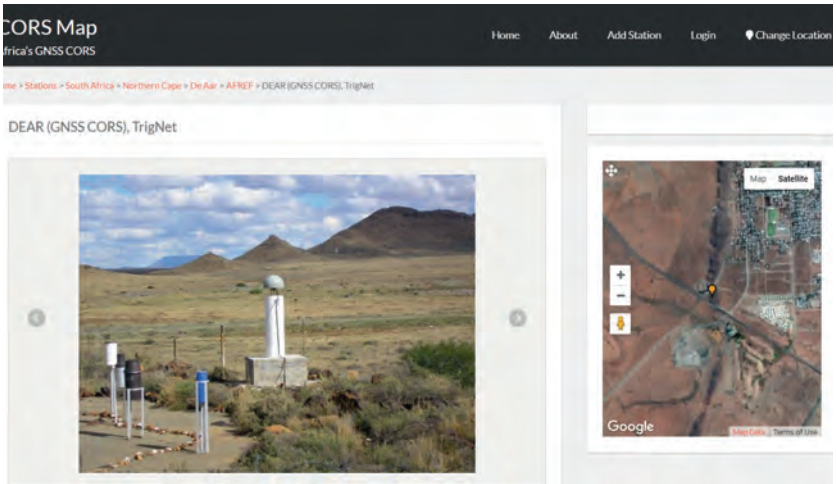


key. It is better to provide limited yet accurate base station information than to have a flood of information that is not factual and truthful. Looking ahead, it is the Corsmap team's dream to have such a network of dependable people uploading the base station data themselves. This will be a true reflection of international cooperation between geospatial professionals. Interestingly, perhaps, the Corsmap founders have created the online map without actually ever having met face to face. Clement is based in California (USA), Eldar in Australia and Derrick in Kenya. Their conversation started on LinkedIn, and the online map is the product of extensive e-mail correspondence and Skype meetings, mostly at odd hours of the day.

PRECISION AGRICULTURE

Permanent GNSS stations can open up a world of opportunities in many sectors. Since African economies are mainly agriculturally based, the mass adoption of precision agriculture would increase the output tremendously. Machine control is another industry waiting to be unravelled in Africa. These industries are reliant on CORS installations providing GNSS observables to their machines. Most surveyors in Africa use base and rover setups when doing their RTK surveys. This means the initial cost of equipment is high should a surveyor think of becoming an independent contractor. If more of these CORS installations were known and, in the case of a lack of CORS, could be speedily installed, the initial cost of acquiring geodetic GPS would be halved.

DATUM REALISATION

Last but not least, datum realisation is of paramount importance and CORS networks help to provide that. Each country in Africa needs to have at least one high order station providing data continuously to the African Geodetic Reference Frame (AFREF) in order to have a unified reference frame for the continent. This has been a continuous challenge since the beginning of the AFREF project and one where Corsmap can potentially help in identifying the gaps. As the Corsmap team continue to map permanent GNSS stations in Africa, their eyes are set on building a central database of CORS stations for the global community:

a database that is people centred since crowdsourcing is a permanent cog in its wheel. It is a journey that has begun and will hopefully have a happy ending. If you would like to be part of the narrative, join the Corsmap community forum. ◀

FURTHER READING
www.corsmap.com

CROSSING THE OCEAN MARKS NEW MILESTONE IN COMPANY'S ADVANCE

How **YellowScan** is Pioneering in the World of **UAVs and Lidar**

YellowScan is one of the most eye-catching companies in today's world of unmanned aerial vehicles (UAVs) and Lidar. From its beginnings as a small start-up created by professional surveyors with the goal to revolutionise the market, YellowScan has since become an established name thanks to a passionate team keen to deliver the best Lidar solutions that enable customers to achieve the best results from their projects. The French company has now decided to broaden its horizons by opening an office in North America. This article provides insight into YellowScan's continuing journey towards making UAVs and Lidar a mainstream solution for mapping and surveying jobs.

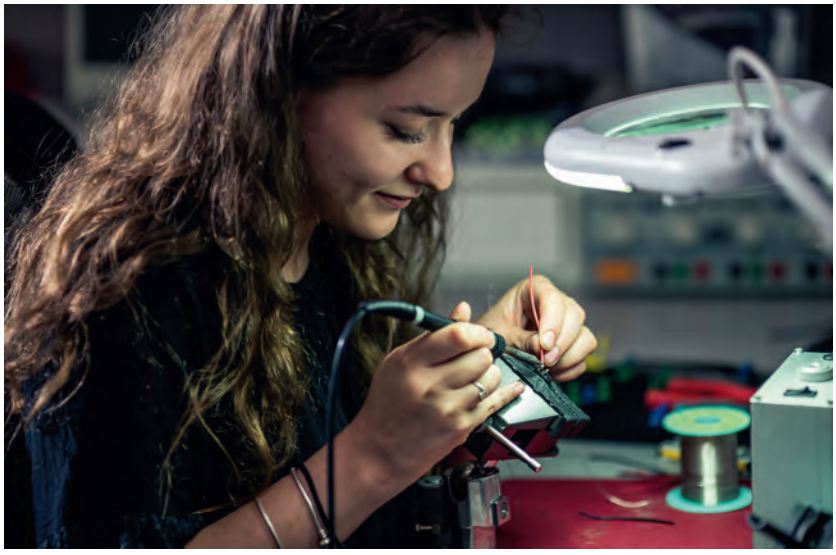
It all started in Montferrier-sur-Lez, a small town in the southeast of France, in 2012 when a group of surveyors decided to create their first Lidar system. The prototype was such a success that they set up a company as a spin-off of L'Avion Jaune, a service-based company providing high-definition aerial imagery. The first Mapper was born, a turnkey Lidar system for under-vegetation 3D modelling. A complete product range has been created since then.

A TEAM BEYOND THE LIDAR SOLUTIONS

YellowScan started with a team of four but over the years this has increased to a crew of 30 highly dedicated experts in their own disciplines, with the company's determination to continuously improve products driving this exciting growth. With a huge investment in R&D, YellowScan designs, develops and produces all of its Lidar systems for UAVs. By constantly improving the technical specifications and the ease of use of its systems, YellowScan's passionate team aims to make it possible for surveyors to fly drones longer and higher, to access remote rugged terrains and to acquire meaningful accurate data.

'JUST PRESS THE YELLOW BUTTON'

All the YellowScan Lidar instruments are built in line with the same vision: 'Just Press the Yellow Button'. The user-friendly element is regarded as a key pillar underpinning the successful roll-out of the company's UAV-Lidar solutions. The fully integrated systems include a laser scanner, IMU, GPS, embedded computer, storage and battery. They are designed to be easy to use, robust and reliable in order to provide surveyors, civil engineers, archaeologists and environmental scientists with a turnkey solution that can be mounted on any drone to meet their short-time data processing needs. All the systems are delivered with a software package including POSPac UAV (for trajectory post-processing) and YellowScan's own processing software (to generate georeferenced LAS point clouds in the desired projection).



For the IMU, YellowScan works together with Applanix. The integrated GNSS-inertial OEM solutions combined with YellowScan software are designed to improve the productivity of Lidar acquisition by eliminating ground control points (GCPs) and streamlining the data processing. The newest systems, the Surveyor Ultra (the high-density and long-range Lidar system) and YellowScan Vx (the high-precision and long-range Lidar system) complete the 'Just Press the Yellow Button' product line. The successful YellowScan Surveyor is the world's lightest fully integrated Lidar for UAV, and the Mapper II is the upgrade of YellowScan's first Lidar system. LiveStation, the real-time in-flight Lidar monitoring kit (software and radio modems), complements this series.

WELCOME TO THE USA

To support this growth, YellowScan is expanding its presence in the United States

with the opening of a new office in Salt Lake City in Utah. The expansion will allow YellowScan to continuously serve its growing list of customers within the USA and Canada with first-hand local and tailor-made services for this market.
To provide an extensive update, three of the company's experts talk about YellowScan's activities and its Lidar solutions: Pierre d'Hauteville (PdH) who is head of sales and marketing at YellowScan, general manager Cliff Holle (CH) who – bringing over 20 years of experience and tactical know-how of the North American market – is set to head operations at the US branch, and Thibaud Capra (TC) who is an application engineer at the company. Here, they answer questions that reveal the company's DNA, its expansion plans in the North American market and the multitude of possibilities that the UAV-Lidar combination offers to give us a glimpse of the future.

YellowScan was founded in 2012 and has enjoyed significant growth since then. What are the main pillars of your success?
PdH: When it comes to building a successful business, you should focus on a powerful team of people, a rewarding customer experience and a strong relationship with your stakeholders. YellowScan has a team-based culture with an entrepreneurial spirit at all levels. We give our employees the opportunity to succeed and to play a full part in our success story. Today, we are a team of 30 and growing: talented people who are passionate about what they are doing across the world. The field experience of most YellowScan team members and hundreds of projects done since our creation mean that YellowScan is a trustworthy brand created by surveyors. We provide an outstanding customer experience because we know and understand our end users' needs. We support them by giving them the right product to achieve the best results in their projects. The 'Just Press the Yellow Button' product line was born following the same vision, offering robust, reliable and user-friendly YellowScan Lidar solutions. To support this growth, we created strong relationships with our stakeholders. From our suppliers to our distributors, we have created a relationship of trust. We are working with the best vendors because we want the best quality in our Lidar. Our distributors are working with us because we provide a high-end product and they quickly get a return on their investment.

Your mission is to help lead the Lidar revolution in remote sensing and GIS 3D mapping. How does that revolution look?
PdH: This revolution looks very promising. People's perception about UAV technology is changing. We are moving to a better acceptance of UAVs flying in civil areas or beyond line of sight. This revolution may lead to more flexibility in the UAV regulations and, as a result, an increase in the number of projects done with UAVs. The customer tends to be more demanding in terms of quality and productivity to deliver an increasing number of UAV-based projects. To meet the market needs, each year we are working to develop new systems, streamline acquisition and processing workflows or provide services to satisfy the end user's requirements.

YellowScan offers complete solutions, covering the whole workflow. How user-friendly is the complete package, i.e. capturing, processing and visualising the data?
PdH: Our vision can be summed up in one sentence: 'Just Press the Yellow Button'. At YellowScan we aim to always develop products that are as user-friendly as possible to make our end users focus only on their use cases. From capturing to delivering, it can all be done in one day. We have many R&D projects in progress to be closer to the field needs and to make all our Lidar easy to use. As an example, YellowScan LiveStation provides system operators with the immediate and relevant information needed to ensure smooth acquisition even in difficult working conditions. It renders a real-time, three-dimensional representation of the point cloud during flight. Simultaneously, the user interface presents an immediate summary of the system's status. The missions can later be replayed for analysing flight conditions and data.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Over recent years, YellowScan has been developing a growing number of UAV-Lidar products. How would you describe your current product range?
PdH: Each of our systems has different characteristics that can meet a wide range of demands. From research to civil engineering and from forestry to urban mapping, we can support our clients who require fast and detailed 3D terrain mapping, even under canopy. For instance, the new Vx-20, with an accuracy of 2.5cm, is perfect for city planning and infrastructure development where the absolute accuracy really matters. Surveyor Ultra, with its long range and light weight, can fly safely aboard fixed-wings and VTOLs to map corridors and forests.
YellowScan has been working with the philosophy that our products should be able to be integrated on any platform in just a few minutes. Because they are fully autonomous and turnkey, pilots feel safe and Lidar operators are confident they can collect the reliable data they need to their customer's satisfaction.

YellowScan is broadening its horizons and opening a new subsidiary in the United States. What made you decide to expand your activities to North America? And what are your plans there?
CH: Currently, a very large portion of the enquiries we receive are coming from the North American region. We are developing our sales partnerships in this region but, to provide the partners and our end users with the very best service and responsiveness, we decided that it was necessary to open a US office.

How can mapping and surveying professionals in the US (and Canada) expect to benefit from your presence?
CH: By bringing a physical YellowScan presence to this region, we can offer training, sales and technical support to the mapping community. We can do this during US working hours and be much more responsive this way.

How is the demand for UAV-Lidar solutions evolving there, and how does that compare with the trend in Europe?
TC: The US market is very demanding, and it has been continually growing ever since the beginning. It's going to be a great challenge. The trend is about the same in Europe, but I would say things move faster here in the United States, mostly because of the recent talks on and evolution of beyond visual line of sight (BVLOS) flights that are mandatory for certain applications if you're after productivity – and, in the end, that's the name of the game.

ANY PROFESSIONAL WORKING WITH ELEVATED FEATURES SHOULD TURN TO LIDAR; THE PATH TO OBTAINING A POINT CLOUD IS NOT AS CHALLENGING AS IT USED TO BE!

What are the main application areas for UAV-Lidar mapping? And which categories of customers are you targeting?
TC: Applications vary on a large spectrum, but the main ones would be mapping, corridor surveys, mining, civil engineering and forestry. I would not say that we specifically target a particular type of customer, but more that we provide solutions fitting a given customer profile. For instance, the YellowScan Surveyor Ultra is a perfect fit for fixed-wing operations, bringing a very efficient solution to anyone having to cover large areas. I'm mostly thinking about the corridor mapping industry in this case. Another example would be the YellowScan Vx providing great accuracy and precision to clients that are after it, such as civil engineering companies. The Vx-20 is equipped with an APX-20 too, allowing high-accuracy work with very little post-processing required.

Aerial mapping professionals can choose between photogrammetry and Lidar. For which tasks is Lidar the most appropriate solution?
TC: The big difference between photogrammetry and Lidar is that a Lidar is an active sensor. This makes it possible to penetrate vegetation and accurately describe the ground surface, whereas photogrammetry struggles to do so. All in all, I would say that any professional working with elevated features (vegetated areas, power lines, buildings, etc.) should turn to Lidar, which is now made easy to process; the path to obtaining a point cloud is not as challenging as it used to be! You can also combine our units with up to two cameras to colourise the point clouds and still have photogrammetric information and outputs if you need to. In my opinion, one of the best applications for Lidar is power-line surveying. Not only does Lidar give you information on the line, it also facilitates the work concerning vegetation encroachment by being able to measure larger swaths, thus increasing productivity too. Another great application is landslides, subsidence monitoring and crisis monitoring. Given the rapid deployment and the fast processing of Lidar data, one can monitor risky areas easily, even with vegetation coverage. Numerous software solutions are able to run a time-based comparison and provide results in no time, hence improving responsiveness in case of an emergency. ◀

Photo courtesy: David Richard and YellowScan.

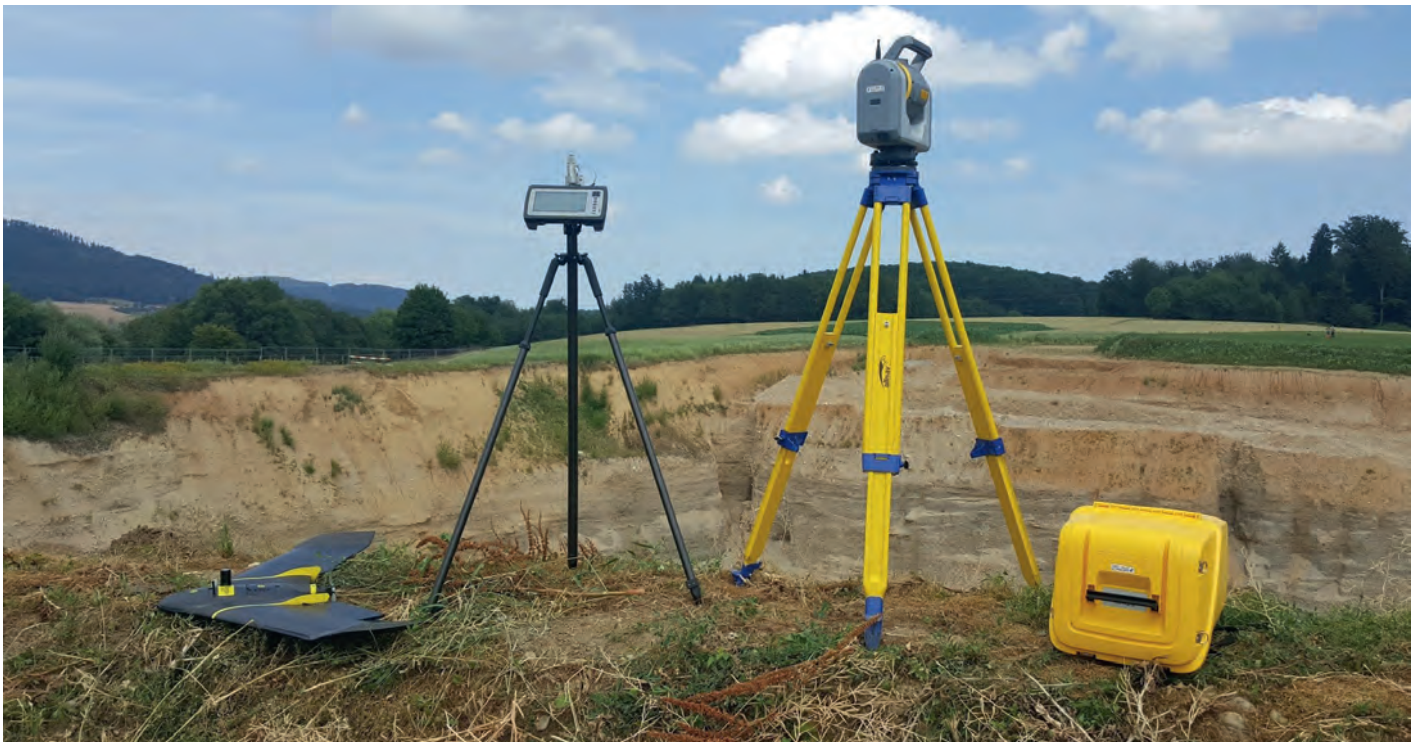
More information
www.yellowscan-lidar.com

ACCURACY, POINT DENSITY, TIME EFFICIENCY AND COSTS

Point Clouds: Laser Scanning versus UAS Photogrammetry

Are photogrammetric point clouds superior to Lidar point clouds, or is it the other way around? To address this topic of ongoing debate, the authors conducted a terrestrial laser scanning (TLS) survey together with an unmanned aerial system (UAS) photogrammetric survey of a gravel pit. Comparison revealed that TLS is superior when the highest level of detail is required. For larger surveying projects, however, RTK-enabled UAS photogrammetry provides sufficient levels of detail and accuracy as well as greater efficiency and improved surveyor safety.

In modern surveying, the numerous measurement methods can be divided into two broad categories: 1) on-site surveying using GNSS receivers, total stations or levels, and 2) remote sensing methods using either laser scanners (Lidar) or photogrammetry. TLS and UAS photogrammetry are popular for many projects. Accuracy, point density, acquisition time, processing time and costs are all important criteria for evaluating performance. A comparison of TLS and UAS photogrammetry on a single project cannot give decisive answers, because the choice depends on the needs of the professional and the characteristics of the



▲ *Figure 1: The SenseFly eBee Plus RTK/PPK equipment (left) and Trimble SX10 scanning total station used in the study.*

▲ *Figure 2: Project site.*

project. Nevertheless, a comparison can help to indicate the relative strengths and weaknesses of TLS and UAS photogrammetry (Figure 1), which was the goal of this study.

SITE DETAILS

A four-hectare gravel pit in the Olten region of north-western Switzerland was chosen (Figure 2) as the site. For such sites, dense point clouds enable users to calculate slope and volume, detect toes and crests and generate contour lines. With a depth of approximately 40m, the gravel pit proved a challenge for UAS photogrammetry, due to the occluded areas resulting in interpolations and a decrease in accuracy. To georeference the TLS stations and to assess the accuracy of the UAS flights, nine ground control points (GCPs) were installed and their coordinates determined using a Trimble R10 GNSS receiver (Figure 3).

TLS SURVEY

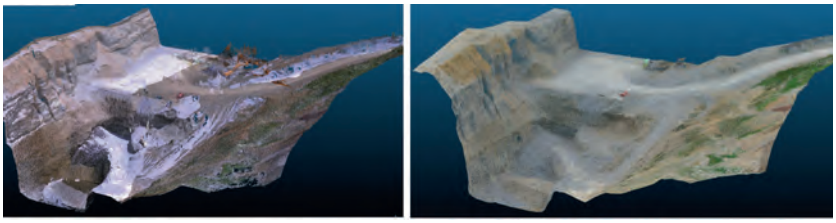
The Trimble SX10 scanning total station was used to perform the TLS survey. Preparation for the survey involved determining the optimal distribution of GCPs and TLS stations. Each TLS station required line-of-sight to at least three GCPs, with these points distributed as evenly over the site as possible. To cover the entire site, three TLS stations were positioned outside the pit and two at the bottom of the pit. To orientate and set the position of the TLS, instrument levelling was required. A 'free station' method was then used to determine the 3D coordinates of the unknown station position with respect to the visible GCPs. On average, the TLS survey took 45 minutes per station, adding up to an on-site survey of nearly four hours.

UAS SURVEY

The UAS survey was carried out using a senseFly eBee Plus RTK/PPK. First, the route and flight boundaries were determined using eMotion 3, the eBee's flight planning and management software. This professional software was used to outline the site, highlight the mapping area and generate flight paths automatically. To assess the influence of ground sampling distance (GSD) on the quality of the point cloud and define the optimum UAS workflow, flights were carried out at two heights: 100m and 150m. The eBee's RTK capability was also used to receive RTK corrections and enhance the precision. This also helped to create four UAS point clouds. PC1 was captured at 100m, PC2 was captured at 150m, and PC3 was a merge of PC1 and PC2. PC1 and PC2 were georeferenced using GCPs. PC4 was captured at a flying height of 100m and georeferenced using RTK corrections only. A meadow next to the gravel pit was chosen as take-off and landing site. With Agisoft PhotoScan, digital surface models (DSMs) and an orthomosaic were generated. Figure 4 shows the TLS DSM and one of the UAS DSMs.

THE TLS POINT CLOUD WAS USED AS REFERENCE FOR COMPARISON OF THE UAS POINT CLOUDS

▲ *Figure 3: Yellow square used as ground control point from which the Trimble SX10 was orientated.*



▲ *Figure 4: Digital surface models generated from TLS (left) and RTK-only UAS (100m flying height).*

PERFORMANCE CRITERIA

Performance criteria included on-site data collection time, in-office preparation time, data processing time and costs. With two UAS flights carried out at different heights and GCPs set across the site, the UAS point clouds could be compared on absolute accuracy and point density. Furthermore, it was considered whether RTK flight alone, i.e. without using GCPs, can give GCP levels of accuracy. Other factors investigated included the impact of flight height/GSD on point cloud quality and the effect on point density of the number of photos used in processing (the higher the flying height, the lower the number of photos).

RESULTS

The georeferenced TLS point cloud and the four UAS point clouds were analysed in CloudCompare and Autodesk CAD Civil 3D; the results are listed in Table 1. UAS point cloud accuracy is at the level of a few centimetres, while TLS points have an accuracy of a few millimetres. In addition to this, TLS produces higher point densities than UAS images. As a result, the TLS point cloud was used as reference for comparison of the UAS point clouds. CloudCompare helped to assess the offset and standard deviation (σ) between two point clouds. AutoCAD was used to complete a volume comparison using the same base surface for all point clouds. Cut and fill volumes were then compared to this surface.

The UAS point cloud georeferenced with GCPs and the UAS point cloud georeferenced with RTK only both showed minimal offset and similar standard deviations with respect to the TLS reference. This indicates that ground control points are not required to ensure high absolute UAS accuracy (Table 2). The TLS point cloud has a very high point density, and while the UAS point clouds are less dense, they appear to show enough detail for most typical survey applications. The noise of the UAS point clouds was not assessed, but when compared against the TLS point cloud showed similar standard deviations and minimal offsets, indicating that the noise from UAS and TLS sources is irrelevant. All point clouds were perfectly exploitable, and the DSMs, volumes and other derived products were not affected. ◀

GROUND CONTROL POINTS ARE NOT REQUIRED TO ENSURE HIGH ABSOLUTE UAS ACCURACY

	PC1	PC2	PC3	PC4
Flight height [m]	100	150	100 & 150	100
Offset [cm]	5.5	6.4	9.4	9.5
σ [cm]	5.2	5.9	5.9	5.8
ΔV [m³]	–4,198	–2,041	619	–1,078
ΔV / Surface [cm]	–0.12	–0.06	0.02	–0.03

▲ *Table 1: Performance of four UAS point clouds using the TLS point cloud as reference; PC3 was generated by merging PC1 and PC2; ΔV: volume difference.*

	TLS	UAS [100m]	UAS [150m]
# points	24,416,594	1,246,951	645,695
Points/m²	741	37	19
Time [min]	225	20	20
Cost (€)	70,000	26,000	26,000

▲ *Table 2: Comparison of performance criteria time including the time needed for on-site data acquisition and in-office processing.*

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REPORT ON FIG CONGRESS 2018

Surveying Profession in Transition

The beautiful city of Istanbul in Turkey played host to the XXVI International Federation of Surveyors (FIG) Congress from 6-11 May 2018. With the theme of 'Embracing Our Smart World Where the Continents Connect: Enhancing the Geospatial Maturity of Societies', the congress brought together more than 2,300 professionals, academics and specialists from over 90 countries to discuss the current and future challenges of surveying. More than 400 papers were presented in a hundred sessions, including joint sessions with partners such as UN-GGIM, UN-Habitat, FAO and World Bank. This article looks back on some of the key highlights of the event.

The welcome address was held by the former and elected presidents of the Chamber of Surveyors and Cadastre Engineers of Turkey, Ertuğrul Candaş and Orhan Kasap. After a short video showing the role of FIG and the surveying profession in the growing world economy, they introduced the dynamic characteristics of Turkey's surveying sector. Dr Orhan Ercan, the co-director of the conference and vice-president of FIG, gave information on the preparations for and scope of the congress. Then Prof Dr Chryssy Potsiou, FIG president, reported on the strategic programme and efforts of FIG in cooperation with international organisations as well as the transformation of the surveying profession for the future. Last but not least Prof Dr Mustafa Öztürk, the undersecretary of the Turkish Ministry of Environment and Urbanisation, painted a detailed picture of the Turkish cadastre and land registry works past, present and future. He singled out real estate as one of the sectors driving the Turkish economy.

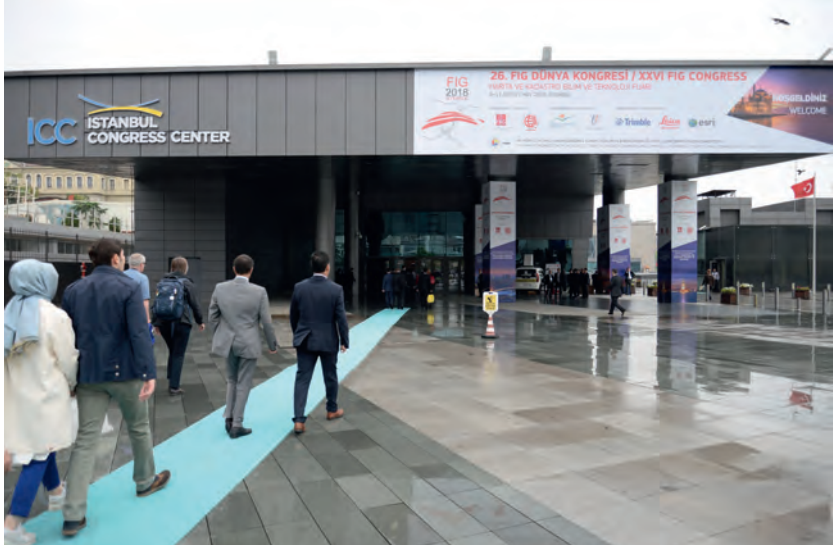
SURVEYING IS TRANSFORMING

The congress provided an overview of the surveying sector as a whole, which is steadily transforming to meet future requirements. Although the precise circumstances vary from country to country, many of the presentations expressed the establishment of an open real-estate market as a common requirement in a globalised economy. Whereas the surveying market has been traditionally local and national by nature, and the professionals within the countries have been protected by local laws, this new development requires a cross-boundary and globally open approach. Many of the presentations referred to Industry 4.0 and the general trend towards digitalisation. In the new digital reality and the world of the Internet of Things (IoT), data consumers are no longer humans but rather complex systems such as robots, autonomous vehicles and online devices. Several industry thought leaders highlighted the disruptive modern technologies that are changing the surveying landscape. In a smart, connected world, this emerging business environment is presenting new challenges and new opportunities that will transform the surveying business and take the profession to the next level. Numerous presentations showed the rich characteristics of data used by surveying professionals, ranging from remotely sensed imagery to mobile mapping, from GIS to BIM, and from GNSS web services to indoor navigation. Results of various studies demonstrated the intersection of surveying with different sectors such as land management, construction, agriculture, transportation, water works, energy, mining and manufacturing. The plenary sessions consistently attracted

▲ *Opening of the exhibition by FIG President Chryssy Potsiou and representatives from Turkey, including members of the Turkish Chamber of Survey and Cadastre Engineers.*

a large audience. Revisiting old problems as well as covering new challenges in surveying, the plenaries provided visionary views on topics including rural and urban development, the modern technology that is transforming the surveying profession and the impact of geospatial data on societal issues and smart societies. Delegates were particularly inspired by real-life projects in developing countries, allowing them to learn from experiences such as the urbanisation policies in Turkey, the sustainable development of rural and urban China, and the role of geospatial data and spatial data infrastructure (SDI) in Singapore's development.

▲ *Opening of the General Assembly of the FIG Council.*



▲ *All participants of the FIG Congress 2018 in Istanbul enjoyed the famous Turkish hospitality, despite the weather.*

LAND MANAGEMENT, VALUATION, GNSS SERVICES, UAVS AND BIM

The congress focused heavily on the outcomes of new applications, methods and technologies for rural and urban development, land management, land consolidation, the position of land valuation in national economies and systems for mass appraisal. The sessions on geodetic surveying covered almost all fields to support surveying infrastructure, such as reference frames, geoid, datum unification, surveying deformation of big structures, improving GNSS positioning accuracy in urban forests, indoor positioning, sub-centimetre GNSS positioning services, IHO safe navigation, and the use of terrestrial InSAR and Lidar for inaccessible terrain. Various presentations on the applications of unmanned aerial vehicles (UAVs) in the fields of archaeology, construction and fit-for-purpose cadastre surveys in remote areas emphasised the prominent characteristics of UAV photogrammetry such as personalised surveying and better visual resolution. Multiple technical sessions covered aspects of BIM surveying from design to construction, predictive maintenance and manufacturing. Besides that, more than 50 people attended the 'BIM for Surveyors' pre-congress event to learn about the latest approaches using BIM/CAD/GIS software. This was followed by a technical visit to Istanbul's new airport which is currently under construction.

FIT-FOR-PURPOSE CADASTRE AND COMPLEXITY IN LAND OWNERSHIP

National organisations for cadastre and land management gathered to talk about topics including the new role of national geospatial agencies in shaping modern society, SDIs, the availability of geodata for robotisation, autonomous driving, automated decision-making, the management and quality control/assurance of geospatial data and one-to-one partnerships, such as the collaboration between Afghanistan and Turkey which aims to re-establish a land administration system in Afghanistan.

Innovative applications, experiences and prototypes relating to the Social Tenure Domain Model (STDM) – a profile of the Land Administration Domain Model (LADM) developed within UN-Habitat's Global Land Tool Network (GLTN) to identify various kinds of land tenure in informal settlements or in customary areas – were presented in joint sessions with UN bodies, FAO and the World Bank. The outcomes of STDM efforts were described as outstanding where developed models responded to the practical needs instead of blindly complying with high-end technological solutions and rigid regulations for accuracy.

In the developed countries, on the other hand, definition and management of property rights in 3D as well as rights in the air and underground are making things more complex. As Lidar and dense image matching make data collection more affordable, 3D cadastre is becoming prevalent, ranging from database management system (DBMS) modelling to partial rights on surfaces and 3D components.

A few of the delegates reported the growing potential for surveying professionals due to global warming and climate change, such as pre-disaster surveying for calculating risk and insurance and post-disaster surveying for calculating hazard and quantity. Besides that, the congress witnessed the efforts of the UN's Food and Agriculture Organization (FAO), delegates and academics to yield satisfactory results for improving surveying

▲ *More than 350 delegates representing 71 of the 105 member associations attended the General Assembly, where they listened to FIG President Chryssy Potsiou presenting the final report for 2015-18.*

protocols and standards on voluntary works for tenure of land, fisheries and forests within the context of the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests (VGGT).

BUSINESS OPPORTUNITIES

The large exhibition area featuring 51 organisations, including the platinum sponsors (ESRI, Trimble and Hexagon Leica Geosystems), was lively and busy during the congress. International technology companies mainly exhibited solutions for surveying, GIS and building information modelling (BIM), whereas local Turkish companies presented their consultancy, engineering and software services aimed at various verticals such as infrastructure, cadastre surveying, urban works and geospatial data management. The exhibition area enabled the delegates to meet and interact with companies in a friendly atmosphere while discussing potential business opportunities.

PARALLEL EVENTS

This year's Young Surveyors Conference attracted more than 130 future surveyors to discuss the evolution of the surveyor role towards data management rather than data creation. They also explored the topic of volunteer work through the Volunteer Community Surveyor Program (VCSP) considering the GLTN needs. A training workshop was conducted to develop common surveying ethics, professionalism and technical skills to move a step closer to realising free movement of professionals across national borders and enabling joint work on global projects. Local municipalities (Sisli and Gaziosmanpasa) supported the FIG Congress by sharing their experiences in urbanisation works as well as sponsoring the social events. Besides that, in line with the tradition of the Consul General of the Netherlands during all international events, professionals and representatives from the Dutch and Turkish associations of surveying societies gathered at Palais de Hollande, home to the first-ever Dutch embassy in Istanbul, where they shared their thoughts and exchanged ideas for future cooperation.

FIG CONGRESS 2022: CAPE TOWN

With attendance of 71 countries, the FIG General Assembly elected Rudolf Staiger from DVW (Germany) as the new president of FIG for the term of 2019-2022 until the next congress. Diane Dumashie from RICS (UK) and Jixian Zhang from CSSMG (China) have become new board members as vice-presidents. New chairs were elected for eight out of the ten Commissions. Furthermore, FIG welcomed two new members: the General Commission for Survey (GCS) of Saudi Arabia and the Afghan Surveyors Association (ASA) of Afghanistan.

After launching an exciting bid against Orlando (Florida), USA, Cape Town (South Africa) was elected to host the next FIG Congress in 2022. This will be the first FIG Congress on the African continent. Until then, FIG Working Weeks will be held each and every year, first in Hanoi (Vietnam) in 2019, followed by Amsterdam (The Netherlands) in 2020 and then in Accra (Ghana) in 2021. The local organising committees of the Working Week events were present in the exhibition area at the congress to promote their events and venues while also discussing delegates' expectations and proposals for content.

Between now and 'Cape Town 2022', members of the surveying profession are likely to face further challenges such as population growth, urbanisation, climate change and new demands in economies and societies. The next FIG Congress is expected to feature some mature solutions for management of geospatial big data, integral models for BIM and 3D cadastre surveying, integrated indoor and outdoor positioning, geodata needs of autonomous driving and robotisation, blockchain technology for democratisation and decentralisation of geodata, as well as some promising outcomes of fit-for-purpose cadastre and land management in developing countries. ◀

MORE INFORMATION

http://www.fig.net/fig2018/
https://www.youtube.com/watch?v=n8PO-RcVEeo

MIXED-REALITY TOOLS REVEAL PRACTICAL ADVANTAGES ON THE WORKSITE

A **New Reality** for Geospatial Professionals

For those who believe mixed-reality solutions are still pie-in-the-sky technology for gamers and super nerds, it may be time to reconsider. Analysts believe we have reached a tipping point in the evolution of virtual and mixed-reality solutions, with enterprise adoption now outpacing consumer markets like gaming and entertainment. According to a recent report by IDC, manufacturing and construction are the two biggest enterprise adopters. This article explores how mixed reality will help surveyors expand their services and gain the flexibility and agility needed to drive more efficient everyday operations.

Mixed-reality solutions merge real and virtual worlds to create brand-new environments where physical and digital components can interact in real time. It is called 'mixed' reality because it encompasses both augmented reality (AR)/virtual reality (VR) and the real world via immersive technology, presenting an image of the real environment overlaid with holographic data from a 3D model. Today's mixed reality applications can help teams better understand how design elements, such as ductwork, would interact with structural elements and other built systems like electrical and plumbing. The ability to visualise highly detailed construction models in the field is poised to transform the way construction work is performed.

MERGING THE PHYSICAL AND VIRTUAL WORLDS

Examples of mixed-reality technology include the Microsoft HoloLens, a wearable, self-contained holographic computer that enables users to engage with digital content and interact with holograms in the real world. When wearing the HoloLens with Trimble's hard hat, which is approved by the American National Standards Institute, users have the ability to manipulate models in the field and leverage the benefits of mixed reality into areas where increased safety requirements are mandated.

▲ *Construction professionals try a new hard hat solution for Microsoft HoloLens on site.*

In addition to hardware such as the Microsoft HoloLens, the technology requires software such as Trimble SketchUp Viewer for HoloLens and Trimble Connect for HoloLens, which improves coordination by combining models from multiple stakeholders such as structural, mechanical and electrical trade partners. The solution does this by enabling precise alignment of holographic data on a 1:1 scale on the worksite so models can be reviewed in the context of the physical environment. These new, immersive mixed-reality solutions are changing the way people interact with digital information. They also demonstrate tremendous potential to spark digital transformation across the architecture, engineering and construction (AEC) industries.

MIXED REALITY AND BIM

Geospatial professionals should be particularly invested in mixed reality's success because surveyors support multiple workflows across building projects by creating and maintaining the coordinate framework, thus playing a pivotal role. This includes extending it to include horizontal and vertical control points, which are used throughout the

construction workflow. Geospatial technology also plays an increasingly important role in 3D building information modelling (BIM) in assessing as-built conditions and precise placement of building components. While BIM has been well accepted by many in the design and architecture realm for delivering enhanced productivity and coordination, the ability to bring that holographic information into the physical space is extending the value of BIM beyond the office to change workflows. From quality assurance (QA) work to check forms before concrete is poured and to comparisons of work orders against the work performed, mixed-reality solutions are bringing constructible models to the field for use in actual building activities.

▲ *The mixed-reality environment blurs the lines between reality and fiction to aid decision-making.*

COLORADO BUILDING PROJECT

During the construction of a building on the Trimble campus in Westminster, Colorado, USA, general contractor JE Dunn Construction employed mixed-reality technologies to validate work plans in advance of actual construction. Users loaded models onto the HoloLens-equipped hard hat for several of the trade foremen from the project's structural, plumbing, architectural and mechanical subcontractors. Using the Trimble solution, the foremen could visualise their components, connections, trays and hangers in the real-world environment. After their initial amazement subsided, they started seeing the practical value of using mixed-reality technology. A mechanical contractor, for instance, saw a large piece of ductwork where cross bracing had not been included on his model, revealing a previously undetected clash with existing steel. Instead, the general contractor and duct foreman created an instant request for information, asking the engineer to resolve the cross bracing issue.

PRACTICAL ISSUES

Mixed-reality technologies provide benefits across the project spectrum, from preconstruction workflows and placing components to aiding QA and enabling quicker decisions. Some innovative and practical aspects of using mixed reality on the worksite are listed below:

• Quality assurance and clash detection

After point cloud data is collected, analysed and registered, total station systems today allow users to lay out directly from the coordinated models and then use a 3D laser scanner to verify correct installations. Taking this preconstruction workflow a step further, users can also load models directly from modelling software to a mixed-reality device like Microsoft HoloLens. Surveyors can then support coordination and QA activities between mechanical, electrical, plumbing and other trades by using Microsoft HoloLens to validate component layouts. This coordinated digital process is much more effective because users can review work on a 1:1 scale and in the context of the actual project, removing the constraints of a 2D computer screen.

• Renovation work and improved safety

In commercial construction, remodels and renovation projects can be particularly complex. Hospital renovations, for example, include numerous systems running in the walls and ceilings, such as medical gas and vacuum systems. Mixed-reality technology can give general contractors and tradespeople the ability to 'see' behind walls and above ceilings without having to take down systems or create safety issues, such as the risk of drilling through a wall and inadvertently hitting an oxygen line.

• Moving beyond the building

Emerging mixed-reality applications that can be used 'outside the building' will also transform GIS by placing visual assets where they reside in a database mapped by a surveyor. For mixed reality in the field for construction or utility contractors, for example, Trimble's SiteVision can be used for project coordination by enabling the constructible model to be visualised on the worksite prior to construction. Also, Augview with Trimble Catalyst's GNSS high-accuracy positioning receiver for Android is helping field crews to visualise underground objects like utilities. Technicians in the field can 'see' the location of buried pipes and conduits in real time to avoid damage, like a line strike or other critical safety issue.

MIXED REALITY TO INTERSECT WITH SURVEY WORKFLOWS

By aiding the visualisation of what was once invisible, mixed reality helps designers, planners, engineers, tradespeople and general contractors move from their screens to the real environment more effectively and efficiently. Mixed reality technology, as part of a larger push toward industry-wide digital transformation, will help surveyors expand their services and gain the flexibility and agility needed to drive more efficient everyday operations. In addition, BIM and virtual design and construction managers who expand their skills around 3D data management, modelling and visualisation will be positioned to enhance customer relationships and contribute to the efficient building and management of complex, multi-phase projects. ◀

FURTHER INFORMATION

IDC's Worldwide Semiannual Augmented and Virtual Reality Spending Guide, https://www.idc.com/getdoc.jsp?containerId=prAP43848718

Construction workers try Trimble Connect for HoloLens for the first time, https://www.youtube.com/watch?v=tAmImhdWYjA

ABOUT THE AUTHOR

David Burczyk is the segment manager for the Field Technology Group with Trimble Buildings. At Trimble, he is focused on the strategic product marketing and development of 3D capture technology, mixed reality applications and robotic total stations for the AEC market.

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VISUALISING THE PAST THROUGH IMAGERY, ARCHAEOLOGY AND HISTORY

The Digital Revival of Ancient Palmyra

The fate of Palmyra, an oasis city in the Syrian Desert, has been vividly transmitted to us by satellite technology in recent years. Through satellite imagery and televised news we have seen priceless ancient monuments pulverised in front of our eyes at this World Heritage site.

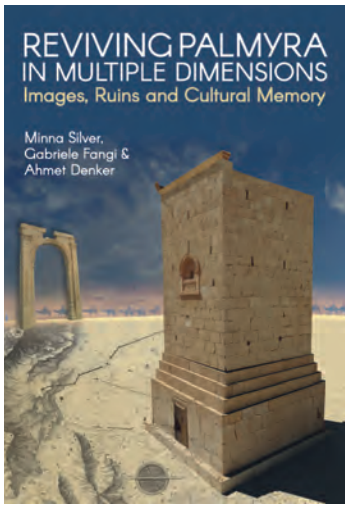
The destruction in Palmyra was carried out from 2015 to 2017 by ISIS, a jihadist Islamic group that occupied large parts of Syria and Iraq at that time. These events could not have been followed without remote sensing. The ancient city represents collective historical and archaeological memories, and its destruction causes additional memories through our visual perception. It becomes part of a distressing experience but is also part of our recollection – there is the memory of the place before and after the destruction.

Even though some media coverage has recently presented it as a brand-new field, archaeological remote sensing with satellite imagery has actually been around for decades. Remote sensing using aerial photographs in archaeology is an even older field of inquiry, over a hundred years old. It first employed cameras from kites and balloons, and later from aeroplanes. Archaeologists are constantly developing and learning new ways to extract information from image-based and range-based data captured from air and space. Remote sensing especially has provided a vital toolkit for archaeologists and cultural heritage professionals in the Near East. The value of such a kit is recognised when we try to find new sites and, in war-torn areas, aim to assess damage and plan site protection and preservation.

Our key question concerns what is left. Records and documentation are needed for conservation and preservation; the information collected and preserved before an episode of destruction has to be traced and retrieved to recollect the sites and monuments in their previous state, even if they were only ruins. There can be information from various 'layers' in time that needs to be collected and studied. This means archaeological digging in our preserved digital data collections that provide the information and enable memories to be revived of the time before invasions and conquests. That data can be fused to impart new life to the memories of the old and provide some collective healing by experiencing the monuments and sites through 3D technology, or even by moving around in virtual spaces in 4D. Use of such information and reconstruction of the site 'memory' with digital data facilitates recall and helps to provide a small substitute for the loss.

A new book called *Reviving Palmyra in Multiple Dimensions: Images, Ruins and Cultural Memory* by Whittles Publishing (UK, 2018) provides a collection of data that an archaeologist/historian, a geomaticist/photogrammetrist and an electrical engineer have put together. Their contribution helps to preserve our common cultural memory and provide healing with diverse archaeological and historical information using photographs, drawings and 3D models as well as virtual worlds to revive Palmyra. The book provides a plethora of old photographs and architectural drawings besides new digital images. This is an especially visual account that is meant for everyone, from people wishing to explore Palmyra to professionals who need to find data for their conservation and reconstruction work.

This highly acclaimed book provides first-hand knowledge from the site, where archaeologist/historian Ad Prof Minna Silver worked with the Museum of Palmyra for a decade and which geomaticist/photogrammetrist Prof Gabriele Fangi visited with his students and colleagues just before the outbreak of civil war in Syria in 2011. Dean Prof Ahmet Denker, an electrical engineer, has lived in the Near East all his life and, as a native in the region, provides the inner and virtual views of the area. Silver and Fangi belong to the UNESCO roster of Syria experts as well as to the executive board of CIPA Heritage Documentation under the International Society of Photogrammetry and Remote Sensing (ISPRS) and the International Council on Monuments and Sites (ICOMOS) under UNESCO.



The book is available in the Geomares webshop: https://geomares-education.com/shop/books/reviving-palmyra

Rudolf Staiger Elected as FIG President

During the FIG Congress 2018 that was held in Istanbul, Turkey, Rudolf Staiger from DVW, Germany, was elected as president of FIG for the 2019-2022 term. Prof Dr-Ing Rudolf Staiger currently teaches surveying engineering at the University of Applied Sciences in Bochum (Germany). His areas of special interest are instrumentation and calibration of geodetic sensors, laser scanning and data analysis. He studied geodesy in Karlsruhe, Germany, and in Paris, France. Rudolf spent six years in the industry with KERN and Leica-Geosystems (both in Switzerland) as a systems engineer, product manager and software developer. From 1994 to 2005 he taught surveying engineering at the University of Essen (Germany). Since then he has been teaching in Bochum, where he also served as vice-president of the university's Institute for Research & Transfer (2009-2016).

Rudolf is a well-known face in FIG and has been active for more than 18 years. Starting as the national delegate from DVW, Germany, for FIG Commission 5: Positioning and Measurement, he chaired a working group on Standards, Quality Assurance and Calibration from 2003-2006. He was the chair of Commission 5 for the 2007-2010 term. Besides that, he was chief editor of the peer review paper system for the FIG Congress 2010 where he also worked on refining the peer review process. Nationally, Rudolf has also served DVW as chair of the Commission 3 (national equivalent to FIG Commission 5) but international relations and cooperation are especially close to his heart. In his campaign for the presidency, Rudolf Staiger stated: "FIG is the only organisation that is representing surveying and geodesy as a profession worldwide. In the times of globalisation, this role of representing our profession is extremely important". Rudolf therefore wanted to continue serving FIG, first as vice president for the 2011-2018 term, and now as president for the 2019-2022 term. In support of his international profile, he speaks not only German but also French and English fluently.

After Heinz Draheim (1970-1972) and Holger Magel (2003-2006) Rudolf is the third German president in the 140 years of FIG. His presidency will start on 1 January 2019.

More information
www.fig.net

GSDI Announces Wind-down of Association

Since its first international conference in 1996 and especially after its formal constitution in 2004, the Global Spatial Data Infrastructure Association (GSDI) has led a global campaign to advance awareness and implementation of spatial data infrastructures worldwide. Today, the association considers its mission to be largely completed and has announced the wind-down of its existence as a legal entity. Throughout the past two decades, the association's mission and purpose has been to enable society to leverage the power of geospatial information and associated tools to improve decision-making relating to, amongst other things, economic, social and environmental challenges that permeate local, regional and international boundaries. Today, many nations around the world have aligned with common SDI principles, practices and standards to facilitate improved collaboration and sharing of geospatial information across multiple domains and thus realised the benefits of doing so.

CAPACITY BUILDING

With a focus on prioritising assistance to developing nations, the GSDI has led educational programmes and capacity building activities, funding over 100 small grants to enable communities to benefit from SDI practices. GSDI members were first in creating knowledge resources like 'The GSDI Cookbook' to help communities rapidly adopt SDI practices for creating, cataloguing, managing, delivering and exchanging geospatial information.
Today those members look back with considerable satisfaction on the successes of their association and the GSDI movement. Whilst acknowledging that additional work, particularly in the developing world, is still required to expand capabilities, and that practices worldwide must be continually updated to take advantage of developments in information technology and evolving policies, they see that their original core mission and purpose has been achieved in

Dave Lovell, GSDI president.

many areas of the world. The GSDI movement has helped to produce a global network of professionals and spawned a number of new organisations and initiatives dedicated to the continued advancement of the benefits enabled through implementation of spatial data infrastructures.

UN-GGIM

With the creation of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), the UN now offers its member nations and GSDI professionals from across the public and private sectors the opportunity to advance the very principles and practices that the GSDI has developed and advanced over many years.

GSDI president, Dave Lovell OBE, FRGS, CGeog, said: "GSDI's members believe the time is right to recognise this moment of opportunity to offer our remaining resources to the UN-GGIM programme and other initiatives which advance activities consistent with our purpose and mission. We therefore are announcing that we will be winding down the GSDI Association as a legal entity over the coming months and using our remaining financial resources to support the United Nations Committee of Experts on Global Geospatial Information Management and specifically to fund developing nations' attendance at this important forum. We believe and sincerely hope that the GSDI mission will continue through the thousands of professionals around the world who have contributed to and benefited from GSDI. The GSDI website will continue for as long as possible to provide a rich information resource for those implementing spatial data infrastructures."

In 2017, *GIM International* talked with Dave Lovell about topics ranging from knowledge sharing and capacity building to big data. The article, titled 'Maximising the Benefit of Geospatial Information' is available via www.gim-international.com.

More information
www.gsdiassociation.org

International Review Workshop on Altimetry Cal/Val and Applications

Organised by the Technical University of Crete and Space Geomatica, the International Review Workshop on Altimetry Cal/Val and Applications was held at the Venetian Arsenali, Center of Mediterranean Architecture, Chania, Crete, Greece, from 23-26 April 2018. More than 70 participants, from countries including India, Taiwan, Australia, United Kingdom, Germany, France, Hungary, The Netherlands, Estonia, Italy, Spain, Portugal, USA, Canada, Greece, Denmark and China, contributed to this workshop. Space agencies and international organisations and institutes such as ESA, Eumetsat, NASA/JPL, Indian Space Research Organisation (ISRO), Centre national d'études spatiales (CNES, French Space Agency), National Physical Laboratory (UK), Metrology Labs (USA), European Reference Frames and Systems, the Danish Space Center and the IAG were all represented.

The aim of the workshop was to present the latest research results in the field of satellite altimetry calibration and altimetry

Participants at the International Review Workshop, Crete.

applications. The intention is to support long-term monitoring of climate change through better understanding of environmental changes in the world's oceans, terrestrial surface waters and the Arctic and Antarctic regions.
Presentations covered topics such as fiducial reference measurements for altimetry, time systems for altimetry standardisation, new altimetry missions from ESA, NASA, CNES, China and ISRO, precise orbit determination, trends in altimetry calibration, estimation of uncertainties for satellite observations based upon metrology standards, calibration of future satellite altimetry, the ESA Climate Change Initiative, polar region applications, modelling of bathymetry, geoid, sea level gravity, heights, etc.
The final outcome has been to establish and promote a scientific roadmap with procedures, protocols, guidelines and best practices, so as to attain traceability of measurements, results and data products.
Support from a number of organisations is gratefully acknowledged. These include ESA, Eumetsat, the IAG, the EU and its Copernicus programme, the Technical University of Crete, Space Geomatica and the Center of Mediterranean Architecture.

Stelios P. Mertikas

More information
www.iag-aig.org

ISPRS Symposium on Education and Outreach 2018

With great pleasure, we invite you to the International Society for Photogrammetry and Remote Sensing (ISPRS) Technical Commission V (TCV) Symposium on Education & Outreach – 'Geospatial technology: Pixel to People' – at the Indian Institute of Remote Sensing in Dehradun, India, from 20-23 November 2018.

In view of the increasing need for geospatial information to support nations' sustainable development goals, innovative approaches for capacity building to cope up with advanced technologies and software solutions are in high demand. Through eight working groups (WGs), the ISPRS TCV is actively involved with pioneers to develop multi-tier training for all levels; cross-border education; e-learning and online web-based resource sharing; citizen science and its societal benefit applications; innovative technologies for training civil engineers and architects; open-source tools and geo-web services.

During the symposium, the WG leaders will present the outcomes of activities and share with the participants their ideas and experiences over the past two years.
Four pre-symposium tutorials are planned on the emerging topics: big data analytics, ground-based 3D modelling, citizen science and its applications, and space education for educators as part of APRSAF. There will be also special lectures from ISPRS and the Indian Society of Remote Sensing (ISRS).
The abstracts and papers will be published in ISPRS Achives and Annals. These will be published in ISPRS Archives and Annals. The deadline for submitting abstracts and papers has now closed.

A. Senthil Kumar

More information
http://www2.isprs.org/commissions/comm5.html
http://tc5-symposium2018.isrs-india.org/

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Communication	
UHF	410-470 MHz
Additional Modules	BT Wi-Fi
Cellular	Internal 4G
Power	2*3400 mAh ,7.4V
Power Consumption	typical 3.8w
Physical	
Size	135*116
Weight	1.1kg
Operating Temp.	-40 C -85 C
Water/Dust Rating	IP67
Shock	1.2m fall onto concrete
Handheld	
Type	HCE320
OS	Android 7.1
CPU	Octa core
RAM+ROM	2GB+16GB
Power	8000mAh, QC support
Camera	8 mp
Water/Dust Rating	IP67
Shock	1.2m fall onto concrete

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