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This issue of *GIM International* is partly dedicated to GNSS. Not only is positioning crucial for today's geomatics professionals (one of whom is pictured on the front cover of this magazine), but GNSS also plays an essential role in people's everyday lives. With an in-depth interview and a comprehensive article on GNSS, this issue brings you up to date on the current status.

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Staying up to date on GNSS

When applying for the position of publisher of *GIM International*, some 12 years ago, one thing I was asked during my interview was to explain some satellite positioning basics. I'm not even sure what my answer was – it probably didn't make much sense – but apparently it was good enough to get me the job. Even after 12 years in the industry, I still continue to be amazed by the technology and techniques that make it possible to identify the position of an object or person almost anywhere on the planet, with an unbelievable accuracy down to just millimetres. Some 80 satellites have changed the daily lives of citizens across the globe forever, and they have changed the lives of surveyors worldwide even more significantly. Those 80 satellites are all part of the constellations making up the four major satellite positioning systems. The oldest and most widely used system is the USA's GPS with 31 satellites, followed by Russia's GLONASS with 24, China's BeiDou with 14 and the European Galileo with 11 satellites and counting. There were considerably fewer 12 years ago! The added value is that, with every new satellite, accuracy is growing all the time. Together with his co-authors, Hans Visser from Fugro-Intersite BV in The Netherlands updates you on the latest developments in GNSS positioning on page 20 in the article titled 'Precise Point Positioning from Combined GNSS'. This edition also contains an article by Kwabena Asiama, Rohan Bennett and Jaap Zevenbergen (University of Twente, ITC) on 'Customary Cadastres and Smartphone Surveys' (page 41). It's sometimes good to remind ourselves that none of these surveys would ever have been possible without GPS and the other positioning systems. I'm sure the inventors of GPS, who were all employed by the United States Department of Defense, never imagined how influential their work would be. But now that we've reached this point, it's necessary to keep track of all the developments that support the growing use of satellite positioning. It's also wise to stay up to date on a regular basis with the latest GNSS-based surveying equipment to ensure its correct and effective deployment to gather high-quality data. I am therefore proud to announce a new Geomares publication: *GNSS Survey & Engineering. Handbook for Surveyors and Survey Engineers** written by Huibert-Jan Lekkerkerk, who is also a contributing editor at *GIM International*. This is not only timely in view of the editorial focus of this issue of *GIM International*, but the publication will also be welcomed by all students who need to learn about the correct operation of satellite navigation equipment in general, and GPS in particular – as well as by surveyors and survey engineers who are keen to brush up on their GNSS knowledge and skills. I, together with the author Huibert-Jan Lekkerkerk, hope that this book will ultimately create a better understanding of GNSS and result in even higher-quality data being collected in the field.


Photography: Arie Bruinsma

▲ Durk Haarsma, publishing director

**To purchase the book, go to the Store on www.geomares.nl or send an email to Myrthe van der Schuit: myrthe.van.der.schuit@geomares.nl*

Decision-making and GIS

The most common use of GIS is as a historian's tool, to describe a situation over time. In this, its value reflects the currency, quality and accessibility of the input data. These factors have generally improved greatly in recent years so in that sense it is unsurprising that GIS has grown so substantially.

But many see the greater role of GIS as a decision-making tool, especially where this involves bringing together data from many sources. How do we know if this really is successful? There are two obvious tests. The first is a necessary condition – does the GIS produce results which can be demonstrated to be correct? This varies by discipline and is easiest when dealing with physical phenomena. Thus outputs from Lidar scanning of buildings can be validated against other descriptors of their position, shape and size. Some systems based on geospatial data can even produce valuable 'snapshot' results by looking into the future (although accuracy checking is inevitably delayed). For instance, small-area meteorological forecasts, based on our understanding of atmospheric physics and global real-time data collection, are now very accurate over short periods in some parts of the world. Future population-change data is produced in many countries by projecting a base level allied to historic rates of change (although these estimates are sometimes perturbed by new surges of migration). Worst of all in quality terms are model-based economic forecasts for nations or regions. These were famously described by J.K. Galbraith who said "the only function of economic forecasting is to make astrology look respectable".

The second and trickier test is to measure improved managerial performance due directly to the use of GIS. Often this is demonstrated solely by the use of qualitative case studies; we should be able to do better.

However perhaps the biggest difficulty in assessing decision-making contributions of GIS relates not to the systems but to the human beings involved. The extraordinary book *Thinking Fast and Slow* by Daniel Kahneman, the psychologist who won the 2002 Nobel Prize for economics, demonstrated how many judgements and decisions are guided directly by feelings of liking and disliking, with little deliberation or reasoning and scant regard for evidence. For example, what if any decision-making success is simply just confirmation bias, i.e. the GIS-produced results happen by chance to agree with the customer's prior beliefs? Who is prepared to tell their customer that he/she is the weak link in decision-making? Do we need to become psychologists to achieve the best results? And might some of our claims about added value from GIS lead us from hubris to nemesis thanks to these human frailties married with inescapable uncertainty?

▲ *David Rhind*

Acuity Technologies Introduces New Lidar System

Acuity Technologies has launched the AL-500 Lidar, a compact omnidirectional scanning range and image acquisition system. It features measurement up to 150 metres in full sunlight with an optional 300 metre capability, and sample rates up to 800,000 points per second. The AL-500 is available in configurations for terrestrial scan acquisition, for real-time industrial and continuous process control in fixed installations, and for mobile land and airborne applications. An available battery pack attaches to the bottom of the Lidar and provides up to eight hours of field operation. IP67 sealing with dry nitrogen fill is standard, and an optional air-cooled version can be used in ambient temperatures above 85°C. A two-axis inclinometer facilitates easy set-up and multiscan registration. The AL-500 measures 83mm by 312mm by 133mm, weighs 4.3kg and is a Class I laser product.

▸ **http://bit.ly/2jZQr2E**

Acuity AL-500 Lidar system.

Geomares and Diversified Communications Announce Cooperation

Geomares and Diversified Communications have announced a cooperation whereby the media company's Geo-matching.com product database will become the official supplier directory for the following trade events and e-media sites organised by Diversified: SPAR3D Expo & Conference, SPAR3D.com, International LiDAR Mapping Forum, Commercial UAV News, Commercial UAV Expo Europe and Commercial UAV Expo Americas. Exhibiting companies at Diversified's events that have an expanded Geo-matching.com profile will be linked directly from the exhibitor list to their profile on Geo-matching.com, which includes information such as company description, contact information, videos, technical specifications, product categories and more. This will give event visitors direct online access to extensive information available only on Geo-matching.com. Meanwhile, the relevant logo of each Diversified event at which those Geo-matching.com companies are exhibiting will be added to their company profiles. This will highlight Diversified's market-leading events in the geospatial arena to Geo-matching.com users.

▸ **http://bit.ly/2jnAUu7**

Integration of CAGIS and ChinterGEO

On 10 January 2017 the China Association for Geographic Information Society (CAGIS) – the biggest association for the Chinese surveying, mapping and geographic information community – held a meeting in Beijing with committee members from ChinterGEO (China's largest trade fair for surveying, mapping and geoinformation equipment). They discussed the changes to the CAGIS Equipment Working Committee and announced the integration of CAGIS and ChinterGEO to further promote the development of surveying, mapping and geoinfomation equipment in China.

▸ **http://bit.ly/2k4dk8T**

During the CAGIS meeting.

UAS-based Lidar: A Market Update

One of the most eye-catching developments in the surveying profession is the integration of unmanned aerial systems (UASs) and Lidar. Airborne laser mapping is no longer restricted to traditional aircraft only, but is now also available for unmanned aerial vehicles. UAS-based Lidar is particularly interesting for surveys carried out over relatively small areas. The quality of the captured data – i.e. point clouds – depends on the sensor performance and the flight-path accuracy. *GIM International* has selected some examples of available solutions for UASs and Lidar in a special section of the website.

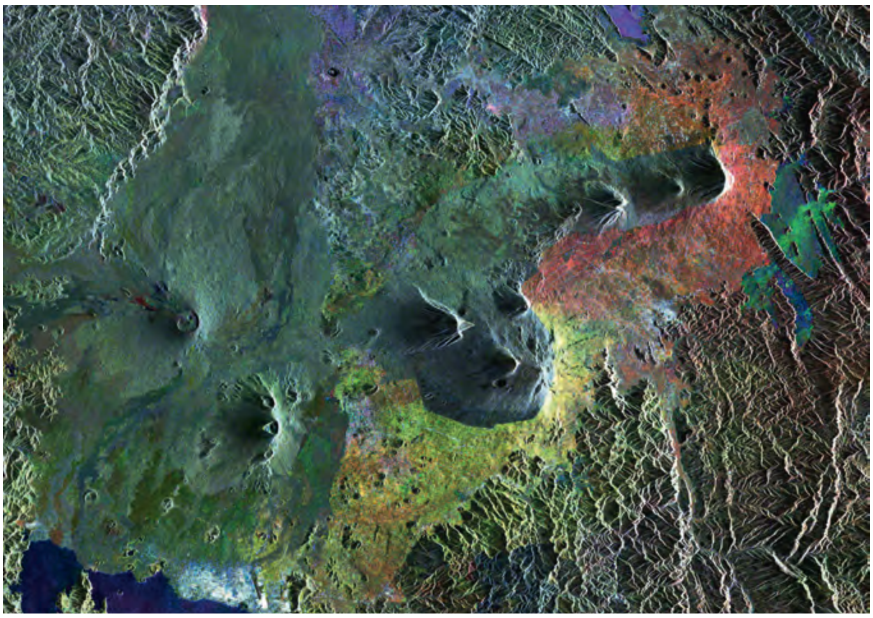
YellowScan Lidar solution.

▸ **http://bit.ly/2ilz5Gw**

Ecometrica Wins GBP14.2m UK Space Agency Contract

Sustainability software and data company Ecometrica has won a contract worth more than GBP14 million from the UK Space Agency's recently launched International Partnership Programme (IPP). The 'Forests 2020' project is set to help countries to improve the management and protection across 300 million hectares of tropical forests – 12 times the size of the United Kingdom. It will also see Ecometrica lead an international consortium that brings together many of the world's leading experts on forest monitoring. The deal, which closely matches the IPP's technology and development goals, is the largest so far to come from the GBP150m UK Space Agency programme, and follows a highly competitive tender process. It is a significant win for Ecometrica, which reported sales of GBP2.77m in its last financial year. Launched in 2016, the IPP brings together British space knowledge, expertise and capability to provide a sustainable, economic or societal benefit to undeveloped nations and developing economies.

▸ **http://bit.ly/2jKrrx4**



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Indoor Spatial Analysis Increases Retail Sales

Esri has announced a partnership with GISinc to analyse customer behaviour to help retailers increase sales. The spatial analytics technology specialist will integrate its spatial analytics platform with GISinc's indoor mapping capabilities to analyse data collected by sensor-enabled overhead smart lighting systems and from opt-in mobile data from customers' smartphones. The solution will enable retailers to track behaviours, using information including customer locations inside the store and items selected for purchase. The store can then tap into such data to improve customer assistance and position merchandise in the places most likely to attract purchases. Analysing customer choices and mapping go hand in hand, according to Sonny Beech, Internet of Things (IoT) business development manager at GISinc. Using ArcGIS analytics enables retailers to make more strategic decisions about where to place merchandise and in-store marketing materials based on spatial data.

Shopping mall in Kielce, Poland.

▸ **http://bit.ly/2iBnqOW**

Million-dollar Boost for Positioning Technology in Australia

The Australian Government will invest AUD12 million in a two-year programme looking into the future of positioning technology in Australia. From using Google Maps on their smartphone to emergency management and farming, most Australians use and benefit from positioning technology every day without realising it. The funding will be used to test instant, accurate and reliable positioning technology that could provide future safety, productivity, efficiency and environmental benefits across many industries in Australia, including transport, agriculture, construction and resources. Research into GNSS accuracy has shown that the widespread adoption of improved positioning technology has the potential to generate upwards of AUD73 billion worth of value to Australia by 2030. Federal Minister for Infrastructure and Transport Darren Chester said the programme could test the potential of satellite-based augmentation system (SBAS) technology in the four transport sectors: aviation, maritime, rail and road.

▸ **http://bit.ly/2iQJSBs**


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5 Questions to... Xiaohua Wen (Tersus GNSS)

The GNSS industry is a very dynamic market full of growth opportunities, as several reports confirm. In China, Tersus GNSS is one of the ambitious companies looking to expand in the international GNSS business. This month, we've asked Xiaohua Wen, founder and CEO of Tersus GNSS, to share his views.

Can you introduce Tersus GNSS to our readers?

Let me tell you a story: in the past, a surveyor's job was not an easy one. It involved manual and time-consuming work with traditional solutions. But one day, a company designed cost-efficient positioning solutions based on real-time kinematic (RTK) centimetre-level positioning. Unlike other solutions, this technology is ideal for many applications: unmanned aerial vehicles (UAVs), autonomous farming, high-precision surveying and mapping. This new technology makes surveyors happy in their daily work thanks to less manual input, greater productivity and more precise data. While a lot of companies are developing GNSS modules and systems for positioning, Tersus GNSS is dedicated to doing it in an excellent yet affordable way and with focus on cutting-edge and high-precision applications for customers. We are a start-up company, heavily investing in R&D to provide the market with solutions that are able to pinpoint objects to within centimetres to ensure accurate surveying and an easier life for surveyors.

What is your view on the current GNSS industry?

The GNSS industry has been increasingly attracting attention in the context of different applications and the global GNSS market has been steadily rising over the past decades. More and more people have recognised the importance of positioning and hence have found new applications for GNSS technology. Location awareness has become a key feature of the latest high-tech products, such as virtual reality (VR), UAVs and autonomous ground vehicles (AGVs). New demands breed new markets. From the technology perspective, BeiDou and Galileo bring opportunities to further improve the performance of GNSS and also the Internet of Things (IoT) is creating new demands for low-cost and low-power location trackers.

What does Tersus GNSS add in the highly competitive market?

Tersus GNSS is currently dedicated to the high-precision, multi-GNSS market; we provide a flexible, high-performance OEM board to help our customers build their own applications. In addition to the surveying market, we are targeting the new GNSS markets such as UAVs, AGVs, machine control and guidance. We provide compact, energy-efficient, well-designed OEM boards for system integrators and design the best high-precision solutions according to their requirements. We are always open to embracing new challenges, new technologies and new applications, which will help us to reinforce our position in the GNSS industry as a whole.

Many new technologies are gaining ground in the geomatics sector. Does this bring new opportunities for a company like yours?

We dare to think about and venture into previously unexplored areas where highly dynamic positioning solutions are needed. For surveying or GIS-related applications, the traditional requirement for positioning accuracy was at metre or sub-metre level, in static mode. However, emerging applications such as UAV surveying & mapping, laser scanning mapping, remote sensing imaging, VR and so on not only require high precision at centimetre level, but also operate in moving, kinematic modes. That presents both challenges and new opportunities for us. Thus, our core RTK technology enables us to be one of the leading surveying instrument suppliers to meet and exceed the needs of state-of-the-art applications, which extend beyond conventional surveying, UAV surveying, autonomous vehicles and high-precision GIS. We are more than ready in terms of products and solutions, and we have accumulated plenty of feedback and experience in real-world cases.

Can you share your expectations about the GNSS industry/technology for the coming years?

Since RTK is not yet deployed in surveying and mapping on a large scale, the costs are still high. The rapid development of unmanned aerial surveying, automatic driving and precision agriculture is bringing RTK technology to a broader market. As a result the price will become more attractive, and the greater market need will further boost the development of RTK. For example, unlike traditional surveying and mapping, which requires clear skies, RTK can be used in challenging environments where there is high interference, multipath effects and occlusions. As RTK technology is developed further and boosted in terms of antenna, baseband and algorithms, it will increasingly be able to overcome all the difficulties.

More information

For more information about Tersus GNSS visit www.tersus-gnss.com.


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Advancing Smart Farming Thanks to Geospatial Technologies

The Netherlands' agricultural exports have hit a new high. In 2016, a record EUR85 billion worth of farming products were shipped around the globe, making the country (with an area of only 41,543km^2!) the second-largest exporting nation in the world. Precision agriculture, also known as 'smart farming', is likely to further boost these export activities significantly in the coming years, as geospatial technologies help farmers to continue to increase their production.

The use of global navigation satellite systems (GNSS) – in particular GPS – has already become mainstream in the agriculture sector. Various machinery guiding and positioning solutions are available for farmers which have increased production and improved the yield per field. Seeding, harvesting and fertilisation are carried out much more efficiently than in the pre-GNSS era. Over the next decade, GNSS is expected to also expand in developing countries to the benefit of local farmers.

However, there is more than GNSS alone. The second geospatial technology that will offer exponential opportunities to the agricultural industry is remote sensing. This sensor-based technology observes the Earth from above and can be done from space – using satellites – but also from aircraft or unmanned aerial vehicles (UAVs or 'drones'). Remote sensing using UAVs is within reach for many farmers, as these vehicles are flexible, small and relatively cheap. The most advanced remote sensing technology is hyperspectral imaging, but this has remained costly so far. There are now a number of interesting initiatives to substantially reduce the costs, however, so things seem to be moving in the right direction. In the meantime, multispectral imaging is a cheaper alternative. Despite being less suitable for specific agricultural tasks, multispectral imaging can still help the farmer to create a prescription map which supports more efficient use of fertilisers or a reduction in pesticides. Multispectral imaging of vegetation also is a good tool to identify crop stress indicators or a shortage (or abundance) of nutrients or water.

The third geospatial technology with a promising future in farming is thermal imaging. This technology has enjoyed rapid growth and has already gained a foothold in various realms of agriculture, such as plant disease detection, nursery monitoring, irrigation scheduling and yield forecasting. Lightweight multispectral and thermal sensors on small UAVs are now reasonably priced and hence more accessible for farmers (see for example the article titled 'Multispectral and Thermal Sensors on UAVs' on the *GIM International* website).

So what is the difference between hyperspectral imaging and multispectral imaging? Hyperspectral imaging divides light into thousands of small bands to capture detailed information, while multispectral imaging works with far fewer bands.
Due to the spectral content in the pixels, hyperspectral solutions add a new dimension in the agriculture sector. The technology has a wide range of applications; it can even detect subtle colour changes on foliage. A UAV equipped with a hyperspectral sensor makes it possible to identify anomalies from 300-400 metres above the crops. This ability to allow farmers to see even the smallest defects in their crops makes hyperspectral imaging a potential game-changer once it becomes widely integrated by farmers.

But what about good, old-fashioned GPS – the global positioning satellite system that has become so vital for so many farmers nowadays? Well, that will remain one of the pillars of modern agriculture. In fact, precise positioning will be the driving force behind the next revolution that will advance smart farming: driverless tractors. No matter whether Google or Elon Musk are already working on them or not – tractor manufacturers such as Case, John Deere and New Holland are, albeit still in the phase of prototypes or autonomous concept vehicles but they will succeed at some point. Farming without driving a tractor…that's certainly something to digest for the diehard farmer. But GNSS will continue to make a mark in agriculture.

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Tractor working in a farmer's field using GNSS. (Photo: Jeroen Verschoore)

GIM INTERNATIONAL INTERVIEWS CARLO DES DORIDES, EXECUTIVE DIRECTOR, GSA

Linking **Space Technology** and User Needs

Space technology has a big influence on the transformation of the way we live, work and play. The core mission of the European Global Navigation Satellite Systems Agency (GSA) is to ensure that European Union citizens get the most out of Europe's satellite navigation programmes. In this in-depth interview GSA's executive director, Mr Carlo des Dorides, talks about Galileo, EGNOS, Copernicus, UAVs, location-based services and much more.

As the leader of Europe's GNSS agency, you are working in an industry that is advancing at a steady pace. Where do we stand right now?

As our GNSS Market Report shows, the global GNSS market remains dynamic. GNSS is used around the globe, with 3.6 billion GNSS devices in use in 2014. By 2019, this is forecast to increase to over seven billion – an average of one device per person on the planet. Smartphones continue to dominate, being the most popular platform for accessing location-based services, followed by devices used for road applications. Other devices may be less numerous, but billions of passengers, professionals, consumers and citizens worldwide benefit from their application for efficient and safe transport networks, in productive and sustainable agriculture, surveying and critical infrastructures.

While all these numbers and forecasts are exciting, I believe the real development – and the most important one, as it allows all of these devices to work better – is the shift towards a true multi-constellation environment. As Galileo joins GPS and other global and regional GNSS systems, the multi-constellation concept is becoming a reality. With 18 Galileo satellites working together with GPS, there are more satellites in the sky, meaning more accurate positioning for the end user. Those using navigation devices in cities, where satellite signals can often be blocked by tall buildings, will particularly notice an increase in positioning accuracy.

Zooming in on Galileo, a long-term project, what will be the potential of Europe's own global navigation satellite system?

On 15 December 2016, we officially declared the start of Galileo Initial Services. Now, for the first time ever, users around the world are being guided using the positioning, navigation and timing information provided by Galileo's global satellite constellation. 20 years ago, with some foresight, the European Union (EU) recognised the need for a European-controlled satellite navigation system, and the result is unique. Whereas the United States' GPS, Russia's GLONASS and China's BeiDou systems – among others – are all operated by their respective militaries, Europe's Galileo programme stands alone as the world's only option for GNSS under civil control. This is an important distinction, especially as the world's dependence on GNSS continues to increase. From individuals to private businesses, the public sector and academia, as more and more services become dependent on the availability of an accurate GNSS signal, the implications of a possible signal failure becomes increasingly dangerous.

But Galileo's real potential isn't found in the satellites, but rather in the services and benefits those satellites create for European citizens and businesses. In terms of economic benefits, the additional accuracy and availability provided by Galileo is expected to enable a range of new applications and services that will benefit from increased positioning reliability, thus further driving economic growth in Europe and beyond. Another benefit already available with Galileo Initial Services is the Search and Rescue service. This service has reduced the time it takes to detect a person lost at sea, for example, or in the mountains from three hours to just ten minutes after a distress beacon is activated. Furthermore, the localisation of the distress beacon has improved from 10km to less than 5km. As a result, lives are being saved. A further Galileo-enabled safety benefit is the EU eCall emergency response system. A new regulation means that all new vehicle models sold in the EU must be compatible with this system as of April 2018, so Galileo-enabled navigation devices will start coming to market this year in preparation for this. On top of this, numerous sectors are set to benefit from Galileo in their own unique ways, including aviation, rail, road transport, mapping and surveying, location-based services, agriculture and the maritime industry.

EGNOS and Copernicus are the two other European Union space programmes. How are they connected with Galileo?

The GSA has been responsible for the EGNOS service provision since 2014, during which time we have supported the uptake of EGNOS to benefit a wide range of users including airports, farmers and surveyors. Needless to say, we plan to build from this experience as we take up responsibility for the Galileo service provision. As Europe's regional satellite-based augmentation system (SBAS), EGNOS is used to improve the performance of GNSS. EGNOS uses GNSS measurements taken by accurately located reference stations deployed across Europe. All measured GNSS errors are transferred to a central computing centre, where differential corrections and integrity messages are calculated. These calculations are then broadcast over the covered area using geostationary satellites that serve as an augmentation, or overlay, to the original GNSS message.

As a result of this, EGNOS improves the accuracy and reliability of GNSS positioning information, while also providing a crucial integrity message regarding the continuity and availability of a signal. This is essential for applications where accuracy and integrity are critical, such as aviation, where GNSS alone does not satisfy the strict operational requirements set by the International Civil Aviation Organisation (ICAO) for use in such critical flight stages as final approaches. However, with the addition of EGNOS, which has been certified for civil aviation since 2011, systems such as GPS and Galileo can/will be able to satisfy ICAO standards.

In terms of Copernicus, Europe's Earth observation system, although there is already a wealth of applications for both European systems, their open data policies will enable the creation of many new services, applications and businesses. Galileo determines a precise position anytime, anywhere around the globe, while Copernicus provides information on the Earth's surface, its atmosphere and marine systems. The joint use of both systems in applications will unleash synergies and result in multiple benefits for users. We are already seeing the benefits of combining these programmes to create sustainable solutions to climate change. For example, both Galileo and Copernicus use satellite signals and data to help develop a better understanding of climate change and environmental issues via the accurate observation and measurement of, for instance, the state of the oceans or the chemical composition of the atmosphere.

How does the GSA cooperate with the GNSS industry?

I like to say that the Galileo equation is made up of four parts: the European Commission, the European Space Agency (ESA), the GSA and the industry. After all, it is ultimately the industrial sector that is developing and operating the Galileo system. But thanks to prior collaboration between the GSA and this sector, Galileo arrives onto the market ready and able for immediate use. In fact, today 17 companies, representing more than 95% of the global satellite navigation supply market, already produce Galileo-ready chips, including key chipset manufacturers like u-blox, Broadcom, Mediatek and Intel, leading European automotive chipset manufacturer STM, Qualcomm – the market leader for smartphone chips – and Spanish technology company BQ, which launched the first European-designed Galileo smartphone in July 2016. An up-to-date listing of all available Galileo-compatible products can be found at www.useGalileo.eu.

To further increase the level of Galileo integration, the GSA continues to work directly with chipset and receiver manufacturers. Through technology workshops, sharing Galileo updates, co-marketing efforts and dedicated funding for receiver development projects and studies, the GSA is working with manufacturers to build an even better navigation experience. As to testing, the GSA coordinated a comprehensive testing programme in cooperation with the European Commission's Joint Research Centre and the ESA. More than 460 hours of tests and 91 hours of live in-field testing have been conducted to verify how different models integrate Galileo signals. This information allows manufacturers to update their technology and get the most out of the system's increased accuracy and reliability within a multi-constellation environment.

What does the GSA do to support mapping and surveying professionals?

As an efficient tool for mapping, EGNOS is widely used by organisations such as utility companies and regional and local authorities for GIS and many mapping applications where the metre-level accuracy is adequate.

Specifically as to the GSA's contribution to this market segment, for several years now EGNOS has been contributing to the growing use of GNSS in real-time mapping solutions by providing metre-level accuracy that is widely available for free. In a nutshell, EGNOS eliminates the need for complex and costly equipment and software solutions and the investment in the required infrastructure of augmentation service providers. EGNOS is available on more than 70% of receivers and has become a de facto standard for European surveying receivers.

The Galileo constellation is most often being employed by high-precision users demanding positioning services with sub-decimetre-level accuracy that can only be achieved using augmentation services (e.g. real time kinematic (RTK), precise point positioning (PPP), etc.). The Galileo Open Service is free of charge and offers either single (E1) or dual (E1/E5) frequency, which further improves such augmentation services as RTK/DGNSS or PPP solutions. The resulting benefits to surveyors, especially in multi-constellation environments, are many. For example, surveyors will enjoy easier mitigation of multipath errors, higher signal-to-noise ratio, increased availability, continuity and reliability, and better operation in such harsh environments as urban/natural canyons or under tree canopies. The Galileo Open Service also provides enhanced protection against spoofing attacks.

In addition, we have Galileo's Commercial Service High Accuracy (CS-HA), which is a dedicated PPP-based service to high-precision applications. CS-HA is planned to directly deliver corrections around the world via Galileo satellites and without the need for an additional communication channel. This will allow for the development of many high-accuracy applications across all segments. Furthermore, CS-HA offers triple frequency with faster convergence time for surveying applications and with an achievable accuracy comparable to RTK.

But of course, all these benefits can only be achieved if the geodetic community is 'Galileo-ready'. According to a recent GSA survey, 77% of responding reference networks indicated that they have enough information to integrate Galileo into their systems, while 41% say they are already fully prepared to use Galileo signals. In total, 78% of reference networks have plans to upgrade to Galileo in 2017.

To facilitate this uptake, the GSA is also heavily involved in several funding initiatives, most notably the Horizon 2020 framework programme for research and innovation. Of particular interest is the current Galileo-3-2017: EGNSS professional applications (IA) call, which focuses on maximising European GNSS differentiators in such professional segments as surveying and mapping. In addition, we regularly sponsor the Council of European Geodetic Surveyors' (CLGE) Young Surveyors Award for applications using Galileo, EGNOS or Copernicus signals.

The geomatics field has seen the rise of unmanned aerial vehicles (UAVs) over the last couple of years. How can the navigation industry contribute to this development?

According to a *Business Insider* report on drones, UAV sales are expected to surpass EUR11 billion by 2021. Playing a prominent role in this growth will be commercial UAVs, sales of which are projected to quadruple over the next five years. This growing market for UAVs is accompanied by growing concerns about their safety, especially as reports of crashes and UAVs encroaching on security-critical spaces continue to make headlines. Luckily, GNSS contributes to a solution. In order to operate safely, UAVs are becoming increasingly dependent on satellite navigation signals, including EGNOS and Galileo, for their precise positioning and orientation information. As a result, UAVs represent a promising growth market for GNSS.

With the recent declaration of Galileo Initial Services, UAVs can now benefit from enhanced levels of precise positioning and orientation. In fact, the winner of last year's GSA Galileo Special Prize, part of the annual European Satellite Navigation Competition (ESNC), was a UAV-based project called UAVs2GNSS. The project utilises Galileo Initial Services to provide surveying engineers with positioning accuracy in urban canyons and vegetated areas. As GNSS signals are often degraded in obstructed environments by skyscrapers, vegetation and geomorphology, the project uses UAVs as intermediate carriers of high-precision GNSS signals that can then transfer the geolocation accuracy to the ground.

Location-based services (LBS) is another important segment for your organisation. Can you give us an update?

Absolutely, LBS really is the future of GNSS. Almost three billion mobile applications already rely on positioning information, and European GNSS applications are supported by several categories of devices – mainly smartphones and tablets, but also specific equipment such as tracking devices, digital cameras, portable computers and fitness gear. Growth in this sector will continue. By 2020, more than two billion units will be shipped every year, rising to more than 2.5 billion units by 2023. By then, the installed base of GNSS devices will reach almost nine billion units. The Asia-Pacific region will play a major role in driving growth in smartphone shipments and, to support the uptake of European GNSS within this region, the GSA is involved in several EU-funded projects, including the BELS project and GNSS.asia. Two areas in particular where positioning information will play a vital role are the Internet of Things (IoT) and the driverless car. IoT is already everywhere, connecting smartphones, tablets and industrial and home appliances and making roads, cities, factories and appliances smarter. The vast integrated network of connected objects and services is expected to surpass a volume of 50 billion by 2020. Of course GNSS, including Galileo, will play a key role in providing the positioning, velocity and timing information required by an increasing number of context-aware applications. Specifically, Galileo brings to IoT better accuracy and availability due to its signal strength in such difficult environments as cities, as well as an authenticated open signal.

As to driverless cars, momentum is now building for autonomous vehicles, with GNSS as a key component. And here, the EU is delivering the policy support to back up this movement. Last April, for example, the transport ministers of all 28 EU Member States signed the 'Amsterdam Declaration'. With this, the European Commission and its Member States, along with the transport industry, have pledged to develop rules and regulations for autonomous vehicles – meaning Europe has a shared strategy on connected and autonomous driving. This clear commitment on the part of the EU also means the GSA can move forward with confidence in its support for research in this exciting new area. In fact, several ongoing research projects are already being funded by the GSA under the Horizon 2020 programme. These include the Indrive, Inlane and Escape projects, many of which involve such European big-name players as TomTom, Fiat and Renault.

What will be the main challenges for the GNSS industry in the coming years?

With the declaration of Galileo Initial Services, Galileo officially moved from the testing phase to the provision of live services. The first services offered by Galileo include the Open Service, Public Regulated Service (PRS) and Search and Rescue Service (SAR) – all of which are available free of charge. Initial Services is the first step towards full operational capability, which will occur when the Galileo constellation is complete by 2020. Between the declaration of Initial Services and full operational capability, additional satellites will be added to the constellation, allowing new services to become available. And here lies one of the key challenges we face, namely the need to balance the development of the Galileo service provision with the need for continued deployment as the programme moves towards full service capability. As the GSA continues to work to maximise adoption across user market segments and to foster EU economic and industrial benefits, we expect that – by the time the system reaches full operational capability – Galileo will be positioned as the second GNSS constellation of choice in multi-GNSS receivers.

Is there anything else you would like to share with our readers?

With the launch of Galileo Initial Services, the GSA officially took over responsibility for Galileo operations and service provision. Now, our main job is to ensure a return on investment from Galileo in the form of clear, across-the-board services and applications for end users. As Europe's link between space technology and user needs, and in line with Europe's new space strategy, the job of the GSA is to keep end-user needs at the centre of Galileo. The GSA is a unique EU body created to ensure that this vital link is established across all user groups. To support this, we must continue to invest in the research, technology and applications needed to bring the benefits of space to all EU citizens. Although it is an exciting time for Europe and space, we are keenly aware that it is also a challenging time. However, I am confident and enthusiastic about the opportunities ahead. By building on our experience and successes with the EGNOS service provision, and backed by a committed team of experts, I have no doubt that we will succeed. As a result, European citizens, businesses and entrepreneurs will benefit from the many innovative opportunities created by European GNSS as Galileo gets to work! ◀

FUNDAMENTAL ELEMENTS PROGRAMME

The GSA launched its Fundamental Elements programme, a research and development (R&D) funding mechanism supporting the development of chipsets and receivers. The programme will run until the end of 2020 and has a projected budget of EUR100 million. The main objective of the initiative is to facilitate the development of applications across different sectors of the economy and promote the development of such fundamental elements as Galileo-enabled chipsets and receivers.

The programme offers two types of financing: grants and procurement. Grants are provided with financing currently foreseen for up to 70% of the total value of the grant agreement, with intellectual property rights staying with the beneficiary (with conditions). 100%-financed procurement, on the other hand, is used only in cases where keeping intellectual property rights allows for the better fulfilment of the programme's objectives.

Fundamental Elements is in addition to, and complements, the European Union's Horizon 2020 research programme, which aims to foster adoption of Galileo via content and application development, and thus focuses on the integration of services provided by Galileo into devices and their commercialisation.

MARKET REPORTS

The GSA regularly publishes in-depth market research, including the GNSS Market Report, which has established itself as the go-to resource for global GNSS market intelligence, and the GNSS User Technology Report.

CARLO DES DORIDES

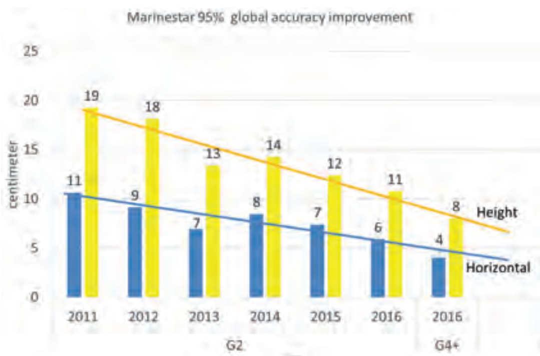
Carlo des Dorides has almost three decades of experience of managing space-service-focused teams. Before joining the GSA as executive director, he held key management responsibilities at the European Commission, where he was responsible for the definition of the Galileo/EGNOS exploitation phase and the EGNOS operational phase. Prior to that, Des Dorides served as chief negotiator of the Galileo PPP/Concession contract at the Galileo Joint Undertaking. In general, his career has been focused on programme management and the operation of advanced satellite systems. As director of programmes and engineering at ENAV, the Italian air navigation service provider, Des Dorides was responsible for updating the technology of Italian airports and area control centres. Before that, he worked in various management positions in the aerospace private sector, including as head of advanced telecommunication programmes for major satellite telecommunications at Alenia Spazio. Carlo des Dorides holds a degree in engineering from the University of Rome and an MBA from CUOA, Vicenza, Italy.

FUGRO MARINESTAR G4+ PPP-RTK DEVELOPMENTS

Precise Point Positioning from **Combined GNSS**

Currently there are four global navigation satellite systems (GNSSs) available: GPS, GLONASS, BeiDou and Galileo. The satellites of these systems are used for positioning and the accuracy is greatly improved if precise satellite orbit, clock and uncalibrated phase delay (UPD) corrections are available when using the precise point positioning (PPP) technique. Fugro operates a worldwide network of reference stations capable of tracking GPS, GLONASS, BeiDou and Galileo systems and this network is used to calculate precise satellite orbit and clock corrections of all four constellations in real time for maritime applications. The corrections are broadcast to users by eight geostationary L-band satellites providing worldwide coverage. This article describes the recent developments and the resulting accuracy of PPP with integer ambiguity resolutions (IAR).

The Fugro Marinestar G4 service uses all four global satellite constellations. However, not all four constellations have the same geographical spread or the same number of available satellites. Therefore, one must consider the strengths and weaknesses of each constellation. The tracking status for each GNSS, based upon a minimum elevation of 5°, is given below.



▲ *Figure 2, Improvements of the Marinestar solution in height over the years.*

GPS

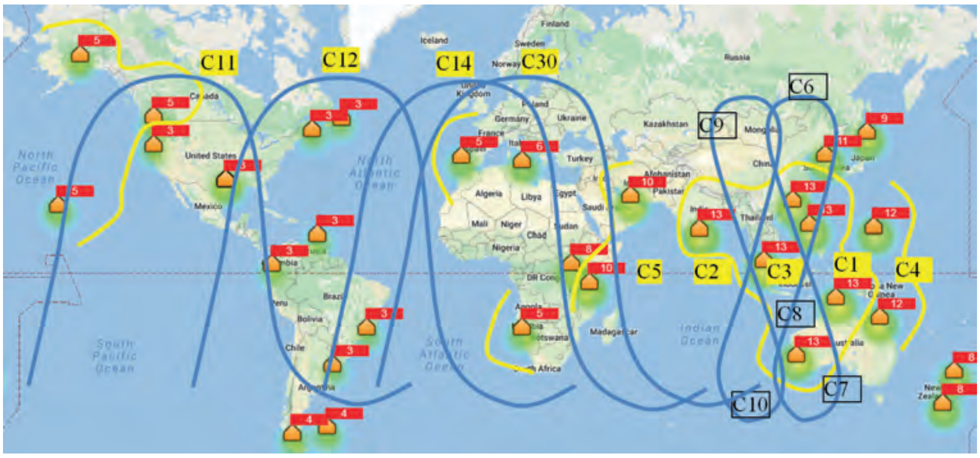
In December 2016 there were 31 healthy US GPS satellites. In the current constellation, 19 Block IIF satellites transmit the additional L2C signal, which is 3dB stronger than the legacy L2 signal. This allows for better tracking in marginal circumstances and no impact on L2C when the L1 signal is jammed (in contrast with the legacy L2 signal, which will be affected). According to the Marinestar GNSS network data, between six and 13 GPS satellites are usable on a daily basis. However, local blockage and interference can reduce this to fewer than 4 satellites for individual users, which is not sufficient for a position calculation using a single system. Positioning can be affected by short GPS radio interference.

GLONASS

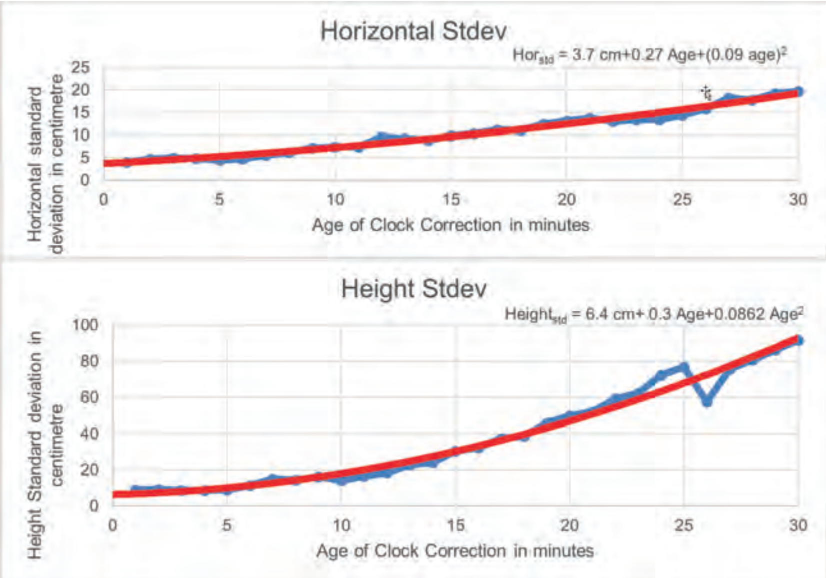
Currently 24 Russian GLONASS satellites are available, with two additional test satellites. Some satellites can have a higher clock noise and are unusable for PPP-RTK so can be removed from the Marinestar service. Between four and ten GLONASS satellites are visible for users anywhere in the world at any one time. GLONASS can be affected by Iridium or Globalstar interference whilst the L2 band can suffer amateur radio interference.

BEIDOU

The Chinese BeiDou navigation system currently has a constellation of 14 operational satellites consisting of five geostationary satellites (GEOs) above the equator covering China, five inclined geosynchronous satellites (IGSOs) and four medium Earth orbit (MEO) satellites. The MEO satellites rotate around the Earth 13 times in one week. In East Asia and Australia, between six and 14 BeiDou satellites are always visible. The MEO's availability in the Americas is between zero and three satellites (see Figure 1).



▲ *Figure 1, Typical maximum number of tracked BeiDou satellites, 21 August 2016.*



▲ *Figure 3, Horizontal (3a) and vertical (3b) standard deviation in centimetres versus age of correction in minutes for the G2 service in Karratha in NW Australia for 10 January 2015.*

GALILEO

Up to December 2016, 18 Galileo satellites had been launched with 11 now available for positioning. Satellites E14 and E18 are in an elliptic orbit and could be used in the future (see [1] Tegedor, ENC2016). There are between two and seven Galileo satellites in view in the network at any one time. A Galileo-only position is possible anywhere in the world for 60% of the time. On 17 November 2016, four extra satellites were launched; two are planned to become available in April 2017 and the other two in June 2017. However, even with just two Galileo satellites in view, Galileo adds value due to the accurate clocks and increased availability of signals and enables Galileo-aided positioning using Fugro's G4+ service.

Based on this overview, it is clear that no single constellation allows consistent positioning for a user. The total number of available satellites right now is 80 (31 GPS, 24 GLONASS, 14 BeiDou and 11 Galileo), and when all constellations are fully established in 2020, there will be 121 satellites (32 GPS, 24 GLONASS, 30 Galileo and 35 BeiDou). Fugro's Marinestar G4+ uses measurements from all four constellations (hence the 'G4' name) and currently broadcasts orbit and clock corrections for GPS, GLONASS, BeiDou and Galileo. Broadcast of Galileo orbit and clock corrections started on 15 December 2016 when the GSA declared the "Galileo Initial Service". Additionally G4+ fixes the ambiguities to their integers on GPS (hence '+') to allow for PPP-RTK positioning (see [2] Tegedor).

ORBIT AND CLOCK CORRECTIONS

Fugro's Marinestar service provides precise point positioning using GNSS data from a globally distributed network of reference stations. Using these stations the precise orbit of each GNSS satellite is determined and transmitted to the user every minute. The satellite clock error is also measured and transmitted with a high update rate.
Over the years the accuracy of the orbit and clock solution has improved: for the G2 GLONASS/GPS solution from 10cm to 6cm horizontally and from 18cm to 10cm vertically (see Figure 2).

Since the newer satellites have more signal power, better antenna gain and better receiver tracking, the minimum elevation can be reduced. Lower elevations help when large parts of the sky are affected by scintillation.

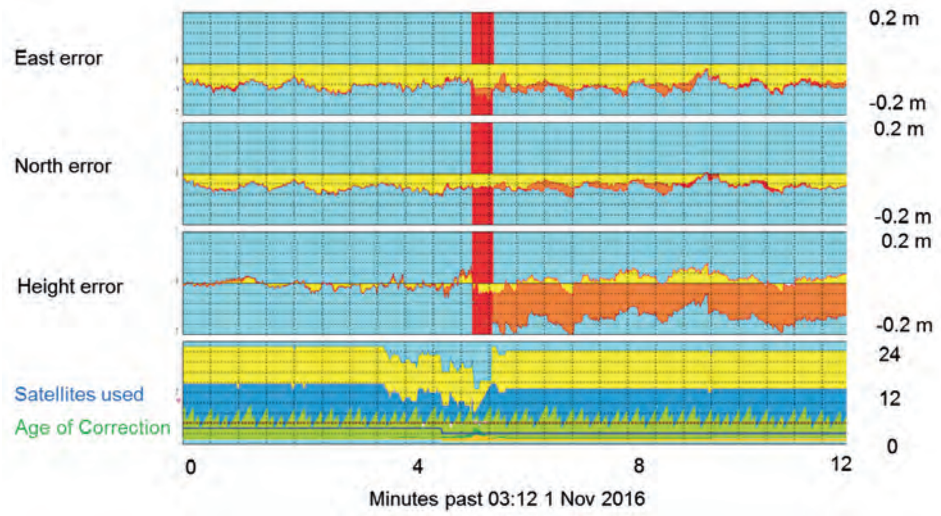
Thanks to improved rubidium clocks in the GPS IIF satellites it is now possible to extend the age of the clock corrections from five to ten minutes and still obtain good results although the position degrades slowly as the age increases (see Figure 3). Increased age helps to overcome L-band scintillation (L-band scintillations last typically less than ten minutes, as does heavy rain at a satellite uplink).

Over time, GNSS satellite clocks can become noisier. Typically, these satellites are within the specifications for general use, but for high-end PPP-RTK services such as G4+ they are a challenge as the variations can be up to 10cm. This clock jitter can also be removed within the Marinestar service.

BENEFIT OF MULTIPLE CONSTELLATIONS

Having multiple constellations provides a benefit. Having more measurements is crucial during heavy scintillation in the equatorial region as seen in Africa and Brazil in 2013-2015. For positioning based on GPS alone, more measurements are crucial because, due to occasionally unhealthy satellites, there are not always sufficient GPS satellites available (see [6] NANU's). The addition of GLONASS measurements significantly improves the situation.

Adding BeiDou to the PPP solution improves availability, although the BeiDou GEO and



▲ *Figure 4, 11 BeiDou satellites (yellow) fixing a GPS L1 jamming position gap (orange) in Perth on 1 November 2016.* ▶

IGSO orbit accuracy is lower due to the larger distance to the Earth. However, the satellites are very helpful in fixing short-term data gaps due to, for example, local interference or cases of GPS L1 jammer interference in which the GPS L1 frequency of 1,572MHz is blocked but the BeiDou B1 frequency of 1,561MHz survives (Figure 4). In the case of Iridium/Globalstar interference, the BeiDou B1 frequency is still tracked while GLONASS L1 – and to a lesser extent GPS L1 – signals can be disturbed.

PPP VERSUS PPP-RTK

The accuracy of PPP can be further improved if the total wavelengths from the receiver to the satellite can be resolved (see [4] Liu). Fugro's Marinestar service offers G4+ with GPS integer ambiguity resolution using additional corrections of satellite UPDs generated within the Fugro network of 100 reference stations. By applying precise orbit and clock corrections in the network of reference stations with inter distances of 1,000-2,000km, it is possible to estimate the UPDs precisely for GPS observations in real time.

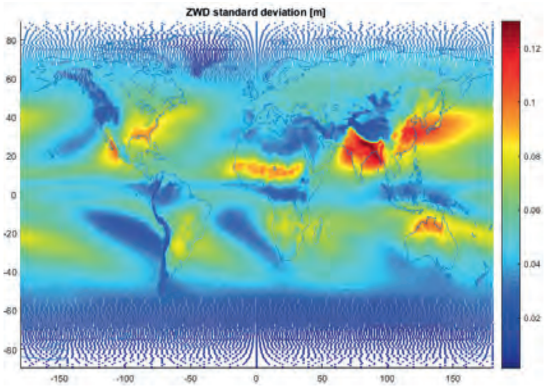
The UPD corrections are broadcast over the satellite links to the G4+ users. In the user's receiver, integer numbers of GPS ambiguities are solved using the LAMBDA method (see [3] Teunissen). The fixed GPS ambiguities are then used in the solution model to calculate more precisely the final position (G4+) solution using GPS, GLONASS, Galileo and BeiDou observations.

Fixing the integer ambiguities requires better measurements than traditional PPP. Items affecting the final accuracy are:

- Radio interference: far-away radio interference, which is normally not noticeable, does affect positioning
- Antenna type: a choke ring or high-end geodetic antenna gives better multipath resistance. However, due to practical considerations, a marine antenna is usually preferred with less multipath resistance
- Tropospheric error: high humidity and heavy tropical rain showers can result in unpredictable, tropospheric range errors (see Figure 5)
- Phase multipath: traditional code multipath in the range of one to five metres affects performance of L1 code. Phase multipath due to nearby reflections of the antenna such as placement on a horizontal pole or close to metal obstructions influences PPP-RTK solutions.

CONCLUSIONS

The quality of Fugro's Marinestar positioning services is continuously improving. Overall and due to the reduced ionospheric disturbances after the solar maximum, GNSS positioning results will be better. The typical accuracy of the G4+ solution is better than 4cm in horizontal and 8cm in height. The horizontal improvement of a G4+ PPP-RTK over a PPP G2 solution is between 6% and 27% horizontally and between 2% and 8% vertically. The improvement in height is limited by tropospheric error. Positioning by PPP-IAR techniques also requires more attention to the receiver-antenna set-up and surveyor's environment. ◀



▲ *Figure 5, 12-year variation of the 'Zenith Wet Delay' tropospheric error (image courtesy: Sam Storm van Leeuwen).*

FURTHER READING

- [1] J. Tegedor (2016), The Galileo contribution to Fugro's G4 precise point positioning service. ENC 2016, Helsinki, Finland, 30 May-2 June
- [2] J. Tegedor (2014), Use of BeiDou in operational precise point positioning service
- [3] P.J.G. Teunissen, The least squares ambiguity decorrelation adjustment: a method for fast GPS integer estimation. *Journal of Geodesy* 70:65–82, 1995
- [4] Liu, Xianglin, Real-time multi-constellation precise point positioning with integer ambiguity resolution, Conference paper IAIN October 2015
- [5] Benton, C. J. and Mitchell, C. N., 2014, Further observations of GPS satellite oscillator anomalies mimicking ionospheric phase scintillation. *GPS Solutions*, 18 (3), pp. 387-391
- [6] http://www.navcen.uscg.gov/?pageName=gpsAlmanacs

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Javier Tegedor holds an MSc in telecommunications engineering from the Polytechnic University of Valencia 2005. He has a PhD in geomatics from the Norwegian University of Life Sciences. His main research topics are multi-constellation orbit estimation, precise point positioning and ambiguity resolution. He is a GNSS scientist at Fugro Satellite Positioning AS.

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3D MODELLING AND WEB-BASED VISUALISATION OF CULTURAL HERITAGE OBJECTS

Investigation of **3D Modelling Techniques**

The rapid developments in the fields of photogrammetry, laser scanning, computer vision and robotics provide highly accurate 3D data. 3D models that can be created from such types of data are highly effective and intuitive for present-day users who have stringent requirements and high expectations. Depending on the complexity of the objects for the specific case, various technological methods can be applied. The author therefore compares three technologies, based on real projects, and assesses their suitability for web-based visualisation of numerous objects of interest.

3D visualisation and proper documentation of cultural objects helps to preserve the history and memories of historic buildings, archaeological sites and cultural landscapes, and supports economic growth by stimulating cultural tourism. Therefore, preservation, visualisation and recreation of valuable historical and architectural objects and places has always been a serious challenge for specialists in the field. However, there are some clear problems that specialists face regarding 3D modelling of cultural heritage objects, such as: proper selection of technology for image acquisition and post-processing, automation of the image-matching procedure, visual and metric quality of the final product, and proper documentation. Low-cost solutions with up-to-date fit-for-purpose technologies are considered suitable for 3D restoration, documentation and visualisation of cultural heritage. Therefore the author compared three technologies in terms of their visual and metric qualities during projects located in Bulgaria – a country with thousands of years of history and cultural heritage spanning several ancient civilisations.

3D MODELLING USING PLANAR IMAGES

3D image-based modelling using handheld cameras is a technique that has been used for various types of objects for decades. For the image acquisition stage, the correct sequence of capturing the images and the proper selection of the capture angle are essential. The images should fully cover the object of interest, which also means that it would be beneficial to have more than the minimum required number. In practice however, especially in highly populated city centres, not everything can be achieved perfectly due to occlusions, reflections of facades with dominant glass coverage, shadows, etc.

For the first test area, the camera used for acquiring the images was a low-cost 20 megapixel non-metric CCD digital Canon IXUS 175 camera which was self-calibrated. For full coverage, between 30 and 70 images per object were needed. Post-processing and 3D modelling was done using AGK Visual Reality from Autodesk. For virtual representation the 3D models were exported in the *.wrl format and visualised via Internet Explorer. In the project, the central part of the city of Sofia was modelled. One of the buildings together with its surroundings is shown in Figure 1. The overall task of 3D models, namely to reproduce reality in a realistic way, was achieved and it was therefore concluded that the visual accuracy was sufficient. However, differences in colour homogeneity, reflective surfaces and shadows affect the overall visual qualities of the 3D models obtained. In this test the metric accuracy of the final 3D models varied from 1m to 3m.

Figure 1, Image-based modelling of the Hilton Sofia hotel.

▲ *Figure 2, 3D visualisation, based on spherical panoramic images, of the Holy Trinity Orthodox Church in Lovech.*

3D VISUALISATION USING PANORAMIC IMAGES

The aim of the second test was to assess the suitability of spherical photogrammetry for photorealistic visualisation of not only one but many important touristic objects simultaneously and to represent them with additional geospatial information in one interactive web portal. The selected historical objects are located in four municipalities in the central part of Bulgaria. Images were acquired with reflex cameras, the Nodal Ninja 5 R plus D16 Rotator. The image acquisition and subsequent web-based visualisation of the selected objects was organised into six thematic, touristic routes (museums, churches, nature, etc.) because the aim was to integrate as many touristic objects from the region as possible. For this reason, a handheld GPS (Garmin) was used for determining their geographic position. To integrate various types of information such as plane and spherical images, maps, sound and video into a single web portal, TourWiever7 software was selected. The overall web portal and each button and menu were designed independently using CorelDraw (Figure 2). The metric qualities of the spherical images were assessed using digital monoplotting for some selected objects where tape measurements were available for reference. In the central part where no distortions were observed the planimetric difference of similarity transformation between the obtained mosaic and the control points was 0.1m for curved objects and 0.01m for planar ones. The final result can be accessed via the following link: http://regtour.lovech.bg/LOVECH_ENG/index.html.

3D MODELLING USING CAD PLANS

For the third experiment in the current study, CAD drawings of a building with a proportionally simple geometry were selected. At the time of the 3D modelling, the building was at the planning stage for construction in the central part of the city of Sofia (Figure 3). AutoCAD and AGK Visual Reality were used for the modelling part. The visual representation for this case depends critically on the experience and personal vision of the creator of the model. This building was actually constructed two years after the planning and modelling were finished, which gave the author the opportunity to make a realistic comparison of the real construction and the model. The achieved metric accuracy of the geometric model was high because all the dimensions

▲ *Figure 3, Photorealistic modelling in Sofia city centre based on architectural CAD drawings.*

were in accordance with the CAD plans. The average error calculated based on several measured distances was 0.01m.

FUTURE IMPROVEMENTS

The 3D modelling of cultural heritage objects is a challenging task, from the data acquisition and gathering of all possible input data through to the final phase of visualisation. Based on the comparison of these three technologies for model creation, the author was able to draw conclusions in terms of their visualisation qualities, metric reliability and usage. In the first two experimental cases, the main sources were images (planar and panoramic). For this reason, the final accuracy is directly related to the image resolution. Despite the problems concerning image acquisition related to both methods, when the constraints are known they can be avoided by a proper selection of the equipment, objects of interest, weather conditions, etc. The success of web visualisation directly depends on the number and quality of the images used. In the third example, in which CAD drawings were used as the main source of information, the accuracy is related to the geometrical quality of the 3D model which has been shown to be at centimetre level. For use in tourism, virtual navigation and the demonstration of numerous cultural objects, spherical panoramas – in combination with tours and additional information – have been shown to be a good solution for visual representation. For damaged historical objects or for buildings still in the planning stage, the overall results show that the third test is most suitable since – providing that CAD data is available – the accuracy obtained with 3D-reconstructed models as shown can be high (0.01m). Therefore, they can be useful for architects and prospective clients in representing various scenarios before a building is constructed.

Using low-cost solutions, the three tests proved that image-based modelling and panoramic visualisation are both simple, fast and effective techniques suitable for simultaneous virtual representation of many objects. For obtaining higher accuracy, however, additional measurements or CAD information will be beneficial. Since all of the above-mentioned methods are time-consuming, it would be better for some of the processes to be automated and integrated.

ACKNOWLEDGEMENTS

This work was supported by GIS-Sofia Ltd. (http://www.gis-sofia.bg/en), Mapex Jsc. (http://www.mapex.bg/en), Videa Ltd., A. Nishkov and the operational programme for regional development. ◀

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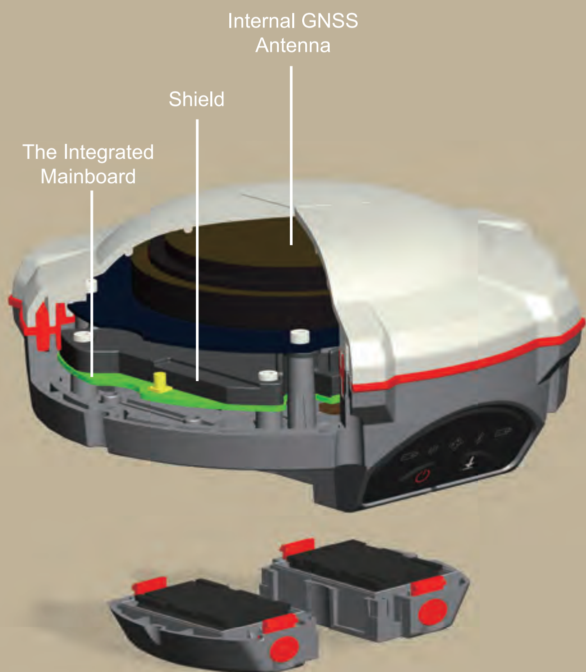

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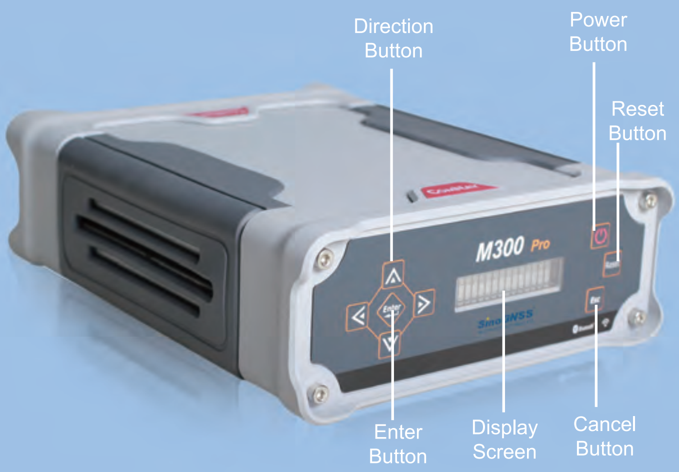

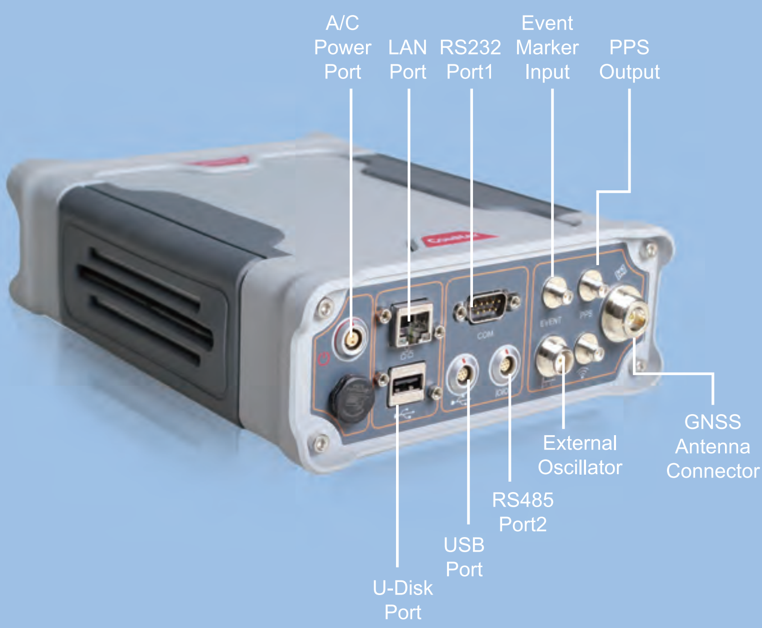

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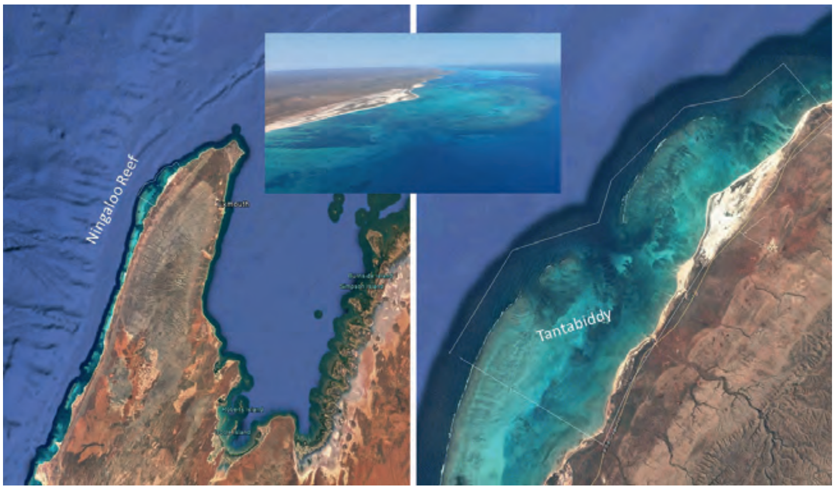
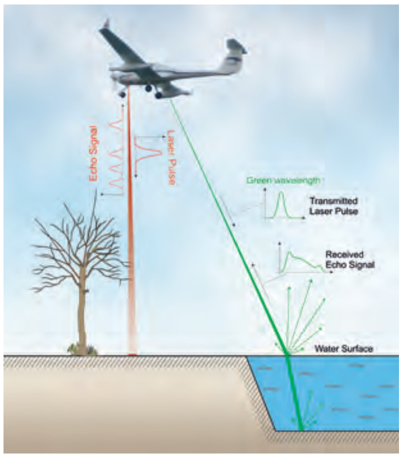
HIGH-RESOLUTION BATHYMETRIC LIDAR FROM SLOW-FLYING AIRCRAFT

Pushing Lidar to the Limits

Airborne bathymetric Lidar is an ideal tool to study underwater features in the usually rather clear waters along the coast of Australia. Due to the remoteness of many of the continent's coastlines, this is often the only economically viable option for large-scale bathymetric mapping at high resolution. A new toolkit consisting of two airborne Lidar systems flown on a small and slow-flying research motorglider was trialled in NW Western Australia. The same technology will be used over the next three years in the context of a comprehensive study of submerged archaeological landscapes of the so-called 'Sea Country', more than 1,000km along the NW Western Australian coast.



▲ *Figure 1: Ningaloo Reef and the Tantabiddy area. Inset: Aerial view of the Tantabiddy area during the flight.*



▲ *Figure 2: Sketch of the arrangement of the two Lidars in the under-wing pods of the ARA research motorglider.*

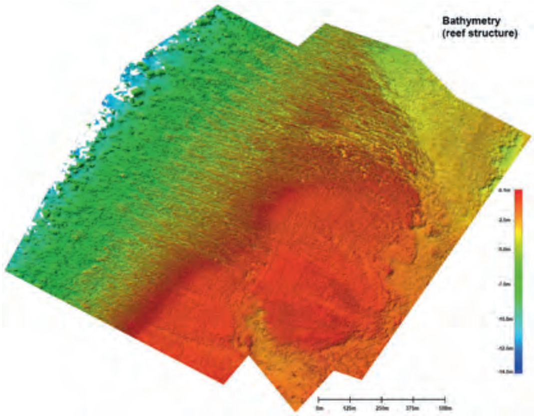
Everybody knows the Great Barrier Reef along the east coast of Australia, but there is also an amazing coral reef along the northwest coast of the country – Ningaloo Reef (Figure 1). Ningaloo Reef waters are famous for their rich marine life, including whale sharks, a slow-moving filter-feeding shark and the largest-known extant fish species. Like the Great Barrier Reef, much of Ningaloo is World Heritage protected.

The waters of Ningaloo Reef can be extremely clear with a water depth of between zero and 15 metres within the reef lagoon. This makes bathymetric Lidar an ideal tool to study the reef's underwater structure in great detail. One of the most interesting areas is the ocean edge, where the reef falls away from just below the water or even a few centimetres above the water into the deeper waters 30m below the coastal shelf just 1-2km from the coast. This is also where most of the larger fish and mammals such as whale sharks, marlins and manta rays can be observed.

ACHIEVING VERY-HIGH-RESOLUTION LIDAR BATHYMETRY

In October 2016 Airborne Research Australia (a not-for-profit independent research institute) flew two RIEGL airborne small-footprint Lidars (VQ-820-G and LMS-Q680i-S) mounted on a slow-flying (manned) motorglider (Diamond Aircraft HK36TTC-ECO-Dimona) over the 50km^2 Tantabiddy area of Ningaloo Reef. The aim was to achieve the highest possible spatial resolution of the bathymetry and – at the same time – gain a detailed image of the wave patterns at the water surface.

The LMS-Q680i-S was scanning downwards with a wavelength of 1,064nm (infrared) and the VQ-820-G Lidar had its 532nm beam swath (green) pointing 20° backwards. The infrared light reflects off the water surface and topography whereas the green light penetrates the water column and reflects off objects underwater (Figure 2). Data was captured along flight lines 250m apart, flying at 600m above the water. As the aircraft can also fly rather slowly (35-40m/s), rather high point densities of more than 30 points/m^2 were achieved for combined data (after removing



▲ *Figure 3: Bathymetry of the western edge of Ningaloo Reef, including the ~500m wide sandbanks within the reef. Spatial resolution is 25cm. Data is a combination of multiple overpasses using different scanner settings.*

noise returns). Simultaneously with the Lidar, data aerial photographs were taken.

MULTIPLE OVERPASSES WITH DIFFERENT SCANNER SETTINGS

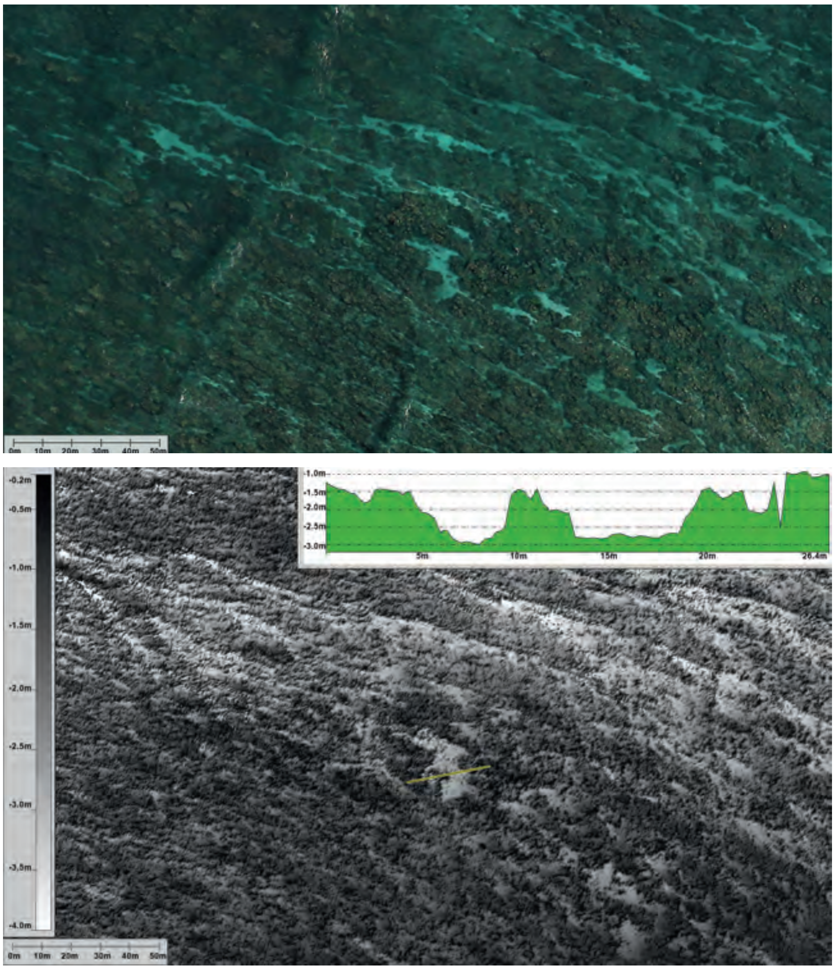
To maximise both the detail of the underwater reef structure and the water depth to which the Lidar was able to resolve the seafloor, two overpasses were flown along each flight line with different settings of the bathymetric Lidar, i.e. pulse rates of 284kHz and 522kHz. The point clouds from both overpasses were combined to ensure best possible alignment by using Bayesian statistics from Bayesmap.com in combination with the LAStools suite from rapidlasso.com. The bathymetric Lidar point cloud was interactively cleaned by inspecting cross sections using the GlobalMapper V17 software.
The double overpasses of each flight line not only offered the unique opportunity to confirm the very high resolution of the bathymetry showing identical details of the reef structure, but also yielded a more complete coverage around the reef edges where some white caps were present. In addition, comparisons with RGB imagery taken during the overpasses were used to further confirm the structural details of the reef bathymetry visually.
Data from the individual overpasses seems to indicate that the green Lidar set to a pulse rate of 284kHz achieves a somewhat better sounding depth – on average between about 20 and 30% – while it achieves a higher spatial resolution when set to 522kHz.

RESULTS

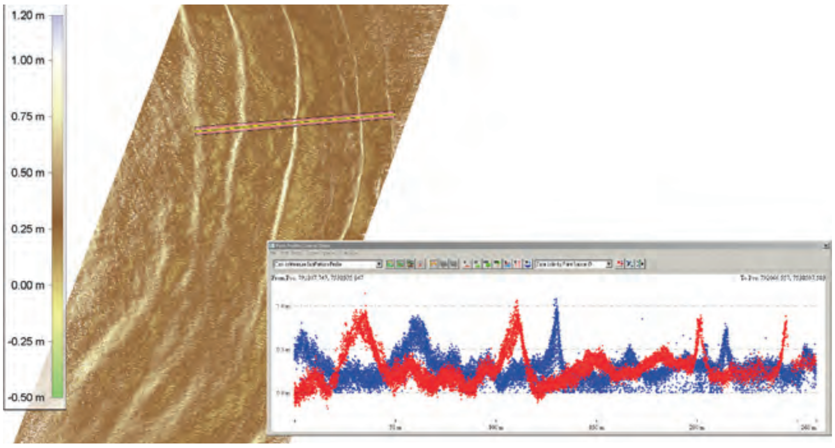
Reef structure
Using the two Lidars enabled accurate mapping of the ocean surface and the underwater topography. Assisted by the near-ideal weather and water conditions at the time, it was possible to map the underwater structure in much greater detail than the data available from earlier surveys, and down to water depths of nearly 15m. As a side benefit, the unique airborne platform ensured minimal impact from the aircraft on the sensitive environment by means of its very low noise footprint and the use of unleaded petrol.
The processed 25cm pixel-size bathymetric data shows elongated ridges approximately perpendicular to the reef's edge, typically between 1.5 and 3m high and 3 to 5m wide (Figure 3). These structures – sandbanks, rocky platforms and even individual rocks – are also clearly visible on the RGB aerial images (Figure 4). Comparisons with available high-resolution data, such as for instance taken from a jet-ski-mounted singlebeam echosounder (but not IMU corrected), along an array of survey lines showed a very similar structure and approximately +/-0.3 metres vertically on average (after alignment of the structures).

Fish behaviour – scope for further analysis
The removal of spurious returns during processing of the data, i.e. the so-called 'de-fishing process', revealed a large number of fish, both individually and shoaling. To derive the reef structure, these data points were eliminated, but they may well enable study of shoaling behaviour itself, especially as there are two independent datasets available about one hour apart.

Wave patterns and wave speed
The point cloud derived from the infrared RIEGL LMS-Q680i-S Lidar enabled the ocean surface to be mapped in great detail in terms of wave structure which can be used to optimise the bathymetric measurements (Figure 5). As the overall wave pattern changed from one series of overpasses to the next (one hour apart), Figure 6 shows data from one series of overpasses only.
When combined with the green RIEGL VQ-820-G data which sees the ocean surface about two seconds later (due to the



▲ *Figure 4: Reef features between 0.2 and 4m under water seen by aerial RGB image (top) and Lidar bathymetry (bottom) – a sandbank and some rocky platforms. Inset: Vertical cross section through the rock and sandbank feature.*



▲ *Figure 6 Wave propagation speed derived from the combination of the green and red Lidar. Inset: Perpendicular cross section of the wave height (red = red Lidar, blue = green Lidar)*

VQ-820-G Lidar's scan swath pointing 20° backwards with the aircraft flying at about 40m/s at 600m altitude), it can even be used to derive an approximate wave train propagation speed from the corresponding peaks in the two images, assuming that the overall wave pattern has not changed within those two seconds (Figure 6).

ACKNOWLEDGEMENTS

The Lidars were operated by Ms Chakravarty. The navigation data was processed by Mr Lieff. The study is a collaboration with Prof Lowe and Dr Hansen (University of Western Australia). The Hackett Foundation contributed substantial funding to the study. ◀

FURTHER READING

An animation of the results in terms of wave patterns and the underlying reef structure, as well as more results, can be viewed on www.airborneresearch.org.au.

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Prof Jorg M. Hacker is founder, director and chief scientist of Airborne Research Australia (ARA), Australia's only non-commercial entity which uses aircraft for environmental research. He is also a professor at Flinders University. He pioneered the concept of using cost-efficient small aircraft for research and has amassed more than 7,000 flying hours, most of them during research missions.

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THE CURRENT STATE OF THE ART IN UAS-BASED LASER SCANNING

Airborne Laser Scanning Using UASs

Airborne laser scanning (ALS) offers a range of opportunities for mapping and change detection. However, due to the large costs typically associated with traditional ALS, multi-temporal laser surveys are still rarely studied and applied. Unmanned aerial systems (UASs) offer new ways to perform laser scanning surveys in a more cost-effective way, which opens doors to many new change-detection applications. This article discusses the suitability of the two main types of UAS platforms – fixed-wing systems and rotorcraft – and the current state of the art in UAS-compatible laser scanning systems.

▲ *Figure 1, Launching a small UAS for a topographic laser scanning mission in the Finnish Arctic. Multi-temporal laser scanning data is collected to monitor Arctic river bed morphology.*

The use of UASs for laser scanning is a relatively new area of research and applications. One of the starting points in 2006 was a remotely controlled helicopter supplied with navigation sensors and a laser range finder (altimeter) suitable for topographic surveys. The use of larger UASs with laser scanners has been studied for almost a decade now and is fuelling plenty of discussion about the possibilities of UAS-based laser scanning in the industry.

UAS PLATFORM COMPARISON

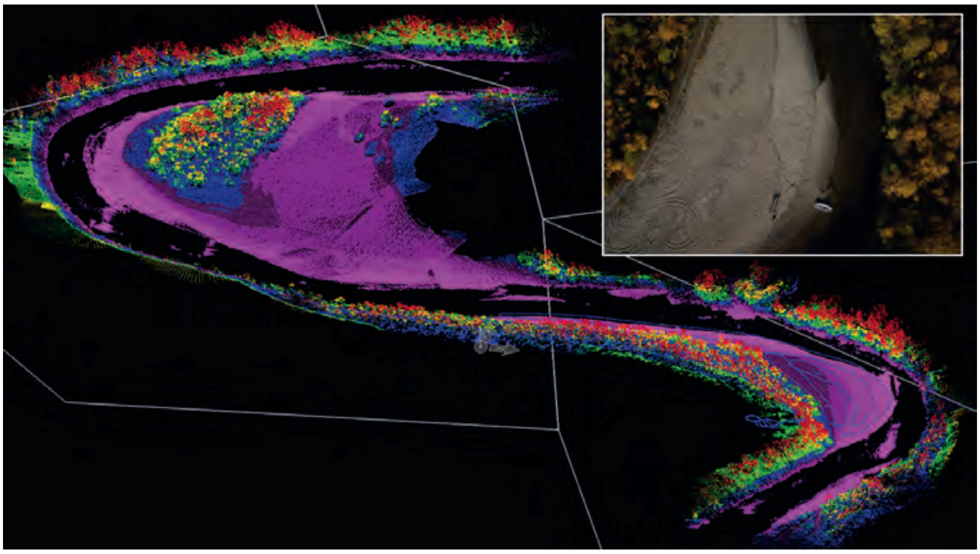
UASs can generally be categorised into two types: fixed-wing aircraft and rotorcraft. Each type is suitable for specific applications and tasks. Fixed-wing systems typically provide users with a longer operation time and support larger payloads due to better fuel economy. Fixed-wing systems also allow for more speed, which makes this type of UAS more suitable for large areas or long-distance missions. The fixed-wing platform is more stable in flight than a rotary-wing platform, the latter struggling with inertia in a more complex way. On the other hand, fixed-wing systems need more space at turns, thereby increasing the path length and decreasing efficiency. In addition, fixed-wing UASs need more space for take-off and landing, which makes them less suitable for remote areas where little or no infrastructure is present. From a data acquisition perspective, the higher speed of fixed-wing platforms reduces data density or requires more-expensive high-performance sensors to reach a certain point density. In summary, these restrictions make a fixed-wing platform less favourable for small-area surveys with complex terrain or objects rich in features that need to be captured. In contrast, rotorcraft allow for slow or even stationary flight speeds. They offer excellent manoeuvrability and do not require an airstrip for take-off and landing. This enables the use of relatively low-cost sensors, which makes UAS-based laser scanning accessible to a wider user community.

INDUSTRIAL SYSTEMS

There are several industrial scanners that are equipped with affordable sensors suitable for UAS laser scanning. Most of these sensors are designed for industrial applications and robotics (manufactured by, for example, SICK, Ibeo and Hokuyo). The main advantages of these sensors are their low price, small size and durability, all of which are advantages for UAS-based laser scanning. However, the performance of these types of sensors is limited. The speed of data collection, ranging accuracy, limited maximum range and often lack of implemented or available signal processing techniques means that they are not always suitable for commercial heavy-user operations, but they suffice for many other (research) applications. Other UAS-compatible systems that have recently emerged are multi-layer laser sensors originating from the automotive industry, such as Velodyne LiDAR Puck LITE and Quanergy M8-1 LiDAR. These systems offer high data rates and some of the other desirable features at a reasonable price. Multi-layer data capture improves the along-track sampling while the 360-degree field of view enables more comprehensive data collection of complex scenes such as the urban environment.

PROFESSIONAL SENSORS

UAS-specific sensors are designed for airborne operations and their specifications make them more suitable for professional use. Their design effort, however, has a clear effect on pricing and the systems from this product class have price tags starting at tens of thousands of euros. Placing such a sensor on a UAS significantly increases the overall system costs. This has a negative impact on exploiting their capabilities for the mapping industry. Examples of professional sensors are Riegl VQ-480-U or VUX-1 variants, which are full-performance sensors. They allow for operations at high altitude (500-1,500 metres). At these altitudes, however, a manned aircraft is often a more convenient approach, also because of the strict regulations for UASs.



▲ *Figure 2, Point cloud data collected with a small UAS for mapping ground topography and vegetation in great detail.*

depends on the wind conditions. This results in a flight path length of between 1.5 and 2 kilometres. With a field of view of 60 degrees and a flight altitude of 70 metres this makes it possible to capture a strip of 80 metres wide. Figure 2 shows an example of point cloud data collected with the Hokuyo UXM-30LXH-EWA for mapping river bed topography. The inset shows an aerial image of the smaller point bar (which was also acquired with a UAS).

UAS-SPECIFIC SENSORS ARE DESIGNED FOR AIRBORNE OPERATIONS AND THEIR SPECIFICATIONS MAKE THEM MORE SUITABLE FOR PROFESSIONAL USE

EXAMPLE OF A LOW-ALTITUDE UAS

The previously mentioned Hokuyo and Velodyne LiDAR Puck LITE are examples of sensors that are suitable for low-altitude missions, which is the typical prerequisite for UAS operations due to safety regulations. These sensors can operate at flight altitudes of up to 100 metres, but in practice typical operation altitudes are 40-70 metres. The flight capability of the small UAS shown in Figure 1 is about 20 minutes including a safety margin, but the flight time also

UAS FOR URBAN REMOTE SENSING

Applications in the urban environment are diverse and may vary from general area mapping for building planning purposes to fine-scale detection of power line components for maintenance purposes. The urban space is often busy. There is little margin for error correction and malfunctions pose a high risk of damage to people and property, meaning that it can be challenging to apply UASs in the urban environment. Nevertheless, it is regarded ▸

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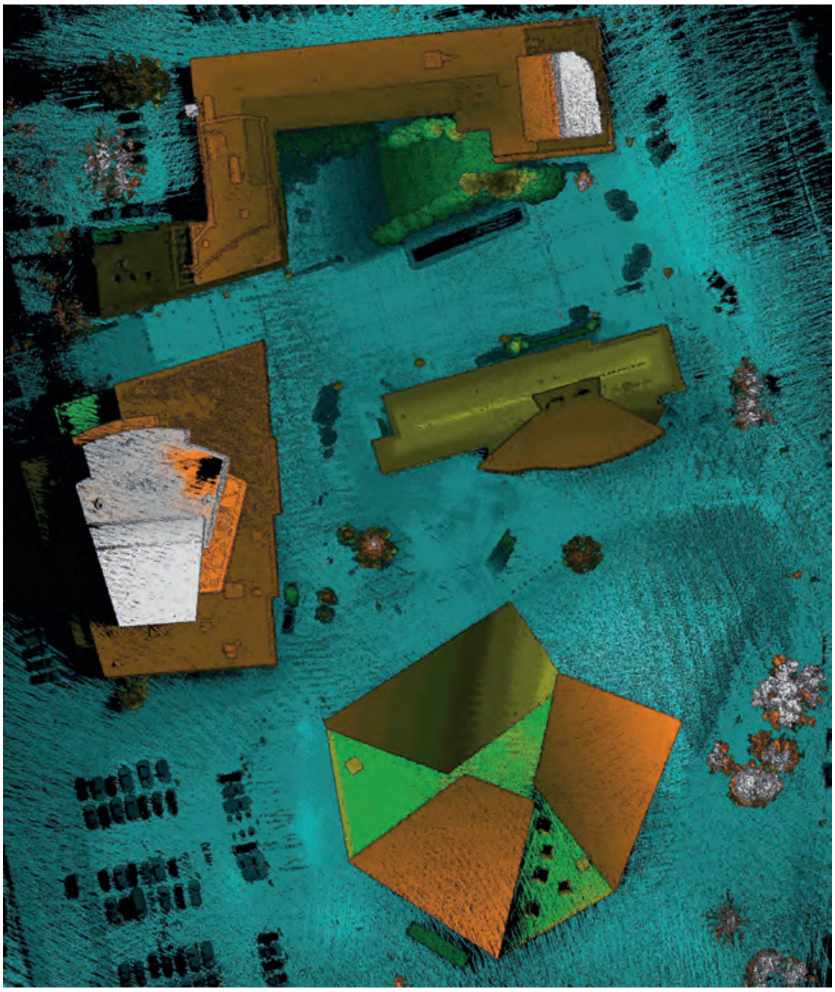

▲ *Figure 3, Architectonic urban scene mapped with a Velodyne LiDAR Puck laser scanner mounted on a small rotorcraft. The 360-degree field of view allows for simultaneous capturing of roofs and walls.*

as an interesting new technology offering a range of new mapping and change-detection applications. The data in Figure 3 was collected using a rotary-wing UAS equipped with a Velodyne LiDAR Puck. The sensor package used here also included a NovAtel IGM-S1 GNSS-IMU device for observing and recording the sensor flight path and orientation. The platform executes the flight plan autonomously while the progress of operation is viewed on a display connected to the system via WLAN. The accurate (corrected) flight path is computed during post-processing using GNSS base station data or data from a virtual network, after which the point cloud data is computed. Point cloud accuracy directly depends on the flight-path solution accuracy but also on the relevant sensor performance. At best, one can expect to obtain a point cloud accuracy of 5 to 10cm. The point densities in the data can be between dozens and thousands of points per square metre, which is a much larger number compared to that of a traditional ALS dataset (1-20 points per square metre). The wide field of view of the sensor allows for simultaneous capturing of the terrain, street infrastructure, building walls and roof structures.

EMERGING TECHNOLOGIES

Looking to the future, flash Lidar technology- (e.g. ASC TigerCub) is a promising development for UAS laser scanning. Flash Lidar allows for fast data acquisition rates with simultaneous areal coverage and overlap due to framed sensing. This enables the multi-look principle for data acquisition, which improves object detection and recognition. However, flash Lidar sensors are very expensive at the moment and, due to their military origin, only limited knowledge

LOOKING TO THE FUTURE, FLASH LIDAR TECHNOLOGY IS A PROMISING DEVELOPMENT FOR UAS LASER SCANNING

is available in the civil domain. Another interesting trend is the development of solid state photon counting sensors in various sizes: larger sensors suitable for use with manned aircraft or large UASs, or extremely small and lightweight sensors based on single photon avalanche diodes (SPAD). In research laboratories, SPAD sensors can reportedly already achieve the same ranging performance as the current low-cost industrial laser scanners. When fully developed and operational, these sensors will definitely change the UAS-based laser scanning field in the years to come. ◀

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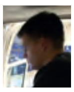

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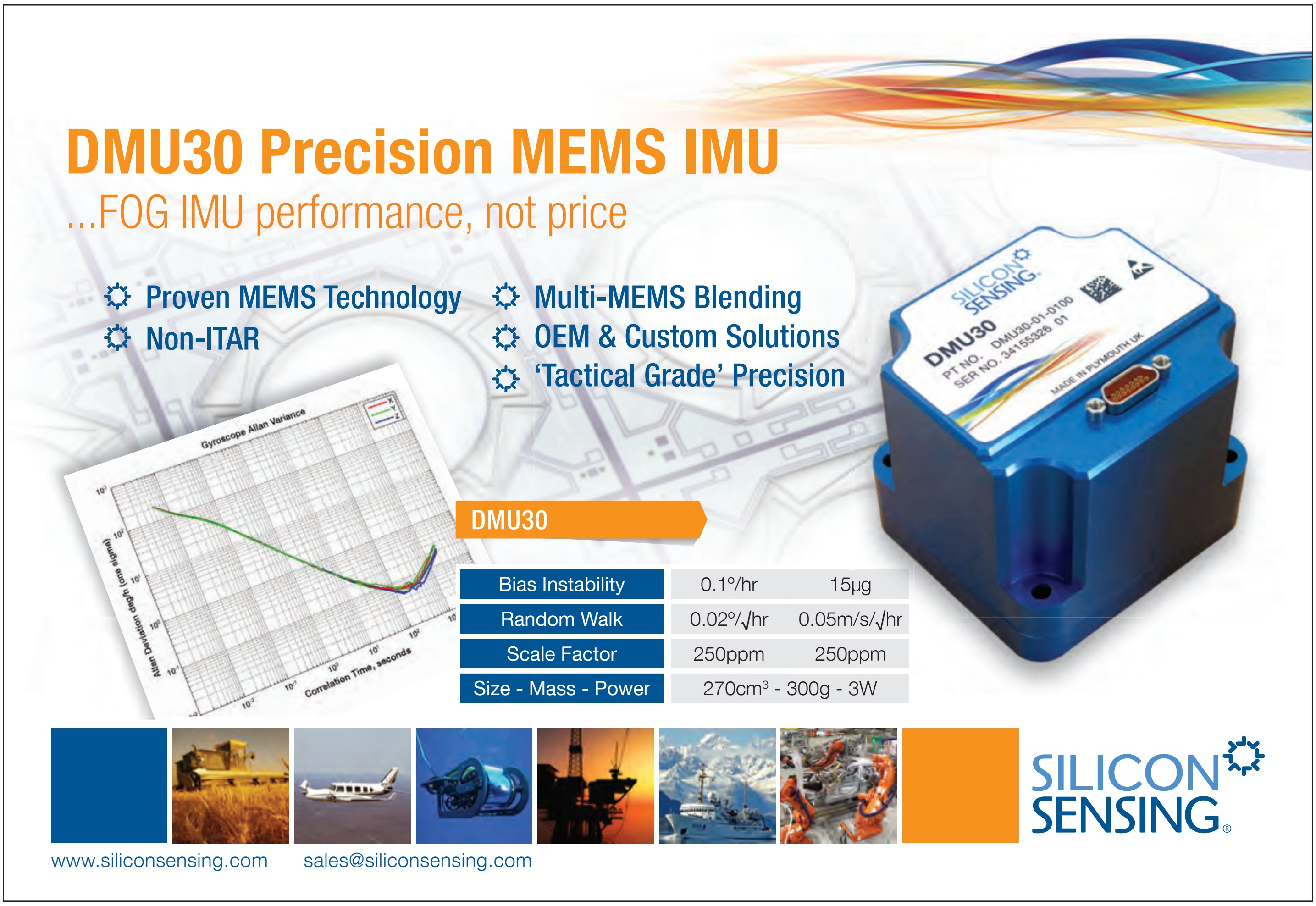
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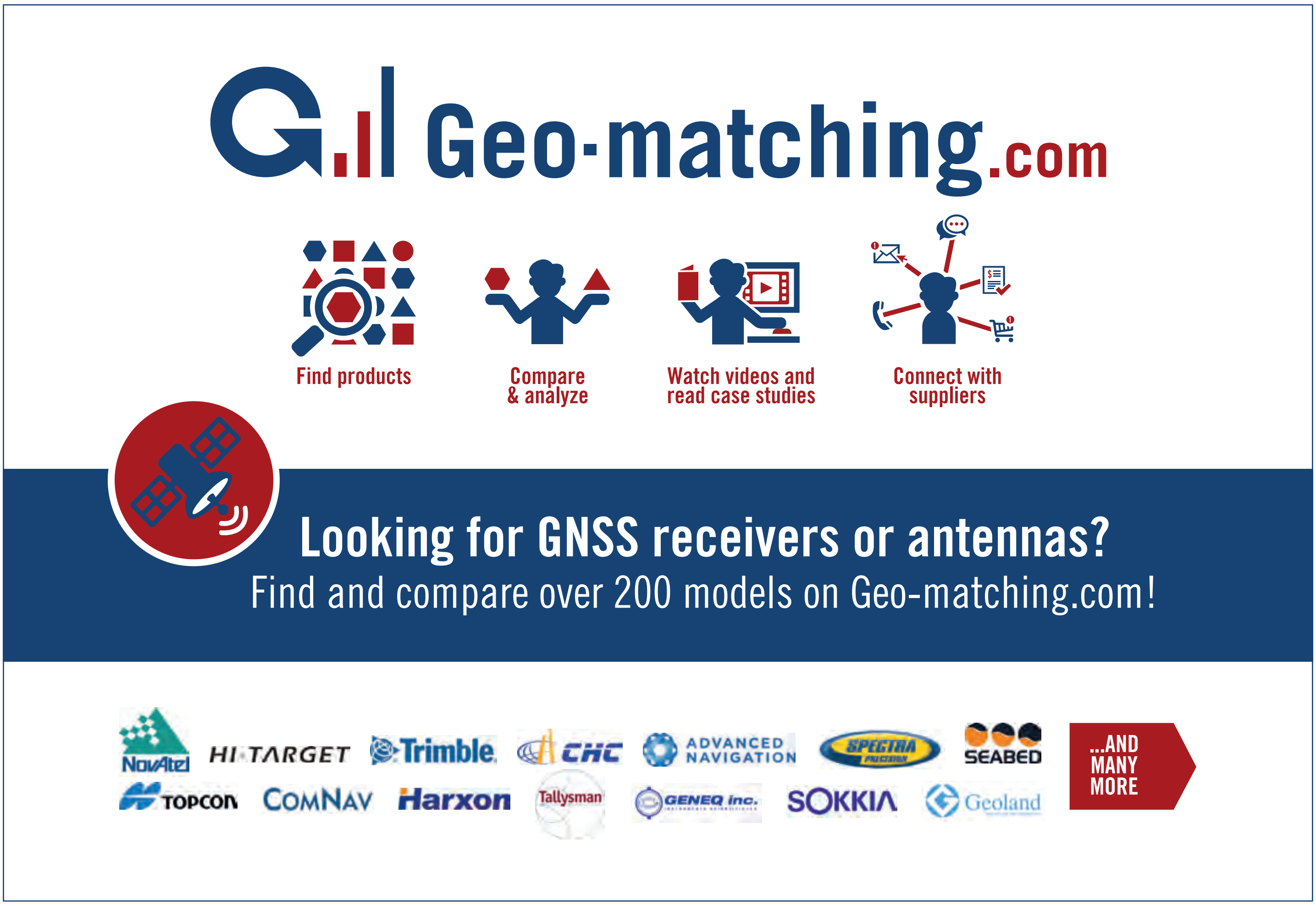
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SINGLE PHOTON LIDAR BRINGS HIGHER PULSE RATES FOR AIRBORNE LIDAR

The **Evolution** of Lidar

Current airborne Lidar systems, such as the Leica ALS series, capture one million points per second. Increasing the pulse repetition rate is the best way to achieve dense point clouds at lower costs, as the flying speed can be increased. However, the pulse frequency is constrained by parameters such as energy consumption and eye safety. Single photon Lidar enables a much higher pulse rate to be achieved, since much less energy is needed per pulse.

Lidar systems are typically constructed from a number of components: a range-finding system, scanning optics to direct the laser pulses, and a position and orientation system to record the origination point of the laser pulse. When employed for airborne Lidar, such a system is sometimes also referred to as 'linear-mode Lidar'.

Linear-mode Lidar systems use relatively high energy in each emitted laser pulse. Each pulse travels from the aircraft to the ground, from where it is reflected back to the scanner. By using more energy per pulse, a stronger reflection can be recorded because more photons are reflected by the terrain below the aircraft. The output from linear-mode systems is impressive and these systems provide data with high spatial and radiometric precision. However, the technology does impose some limitations on the maximum effective pulse rates that can be achieved.

HIGHER PULSE RATES

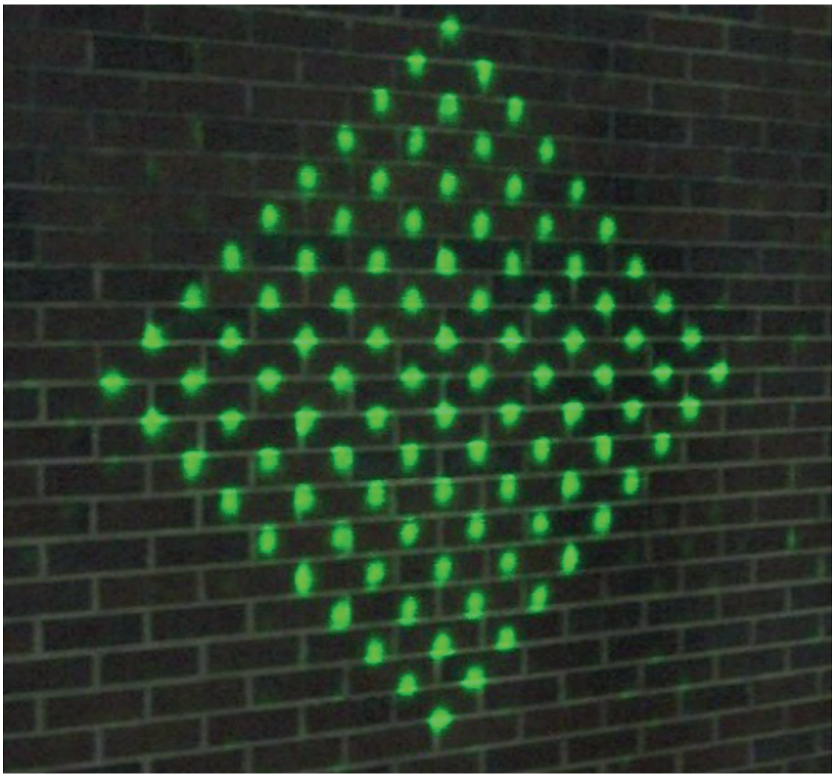
The pulse repetition rate is the most important parameter to define the acceptable flying height and flying speed during data acquisition. A higher pulse repetition rate allows for faster flying while maintaining a similar point density. As the pulse rate of linear-mode Lidar systems increases, so too does the electrical power consumption. In addition, there will be greater heat generation by the lasers used. The ability to generate increasingly higher average optical output, required for ever-higher pulse rates, is an engineering challenge. Besides accuracy and pulse repetition rate, the sensor design should consider total electrical power consumption, system cooling, size, weight and eye safety. This results in limitations on maximum average optical output, thus also limiting the maximum effective pulse rates.

In order to take a next step in airborne Lidar system development, the required energy per pulse must be reduced. This can be achieved by changing the nature and technology of the range-finding system. Next-generation Lidar technologies, including single photon Lidar (SPL), rely on new range-finding systems to achieve lower energy consumption and higher pulse rates.

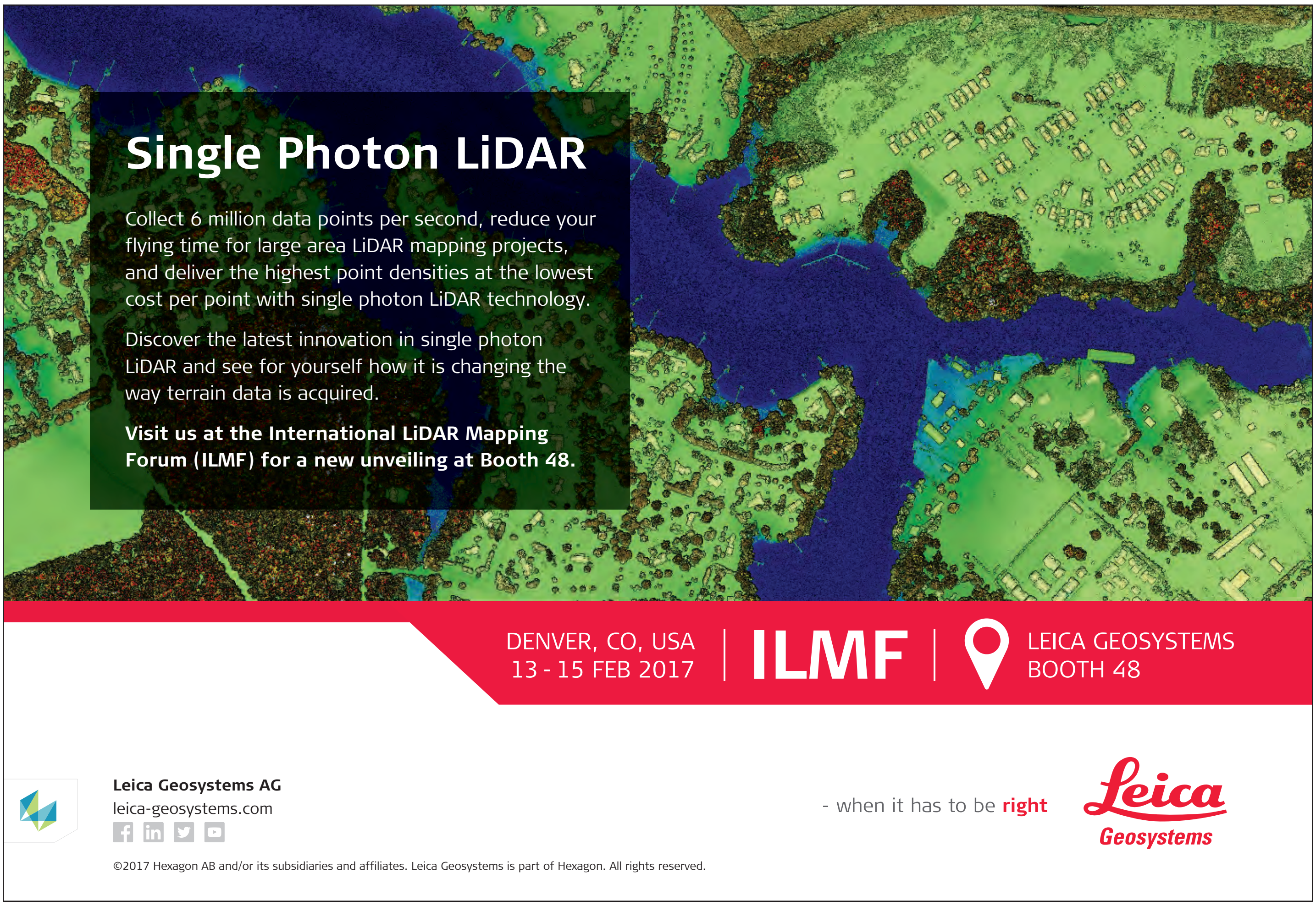
PHOTON COUNTING

SPL was originally developed for Earth-to-satellite ranging and has proven to generate accurate range measurements using a minimal amount of laser energy in each pulse. Compared to currently available linear-mode Lidar systems, SPL allows range measurements to be made from as little as a single photon reflected from the terrain below the aircraft. This level of sensitivity allows a given amount of laser output to be allocated to higher pulse rates with lower energy in each pulse.

The SPL system contains a laser splitter, which splits each laser pulse into an array of ten by ten small laser beams (Figure 1). For these 100 beamlets, the travel time



▲ *Figure 1, The 100 beamlets from the SPL system, visible when aimed at a wall*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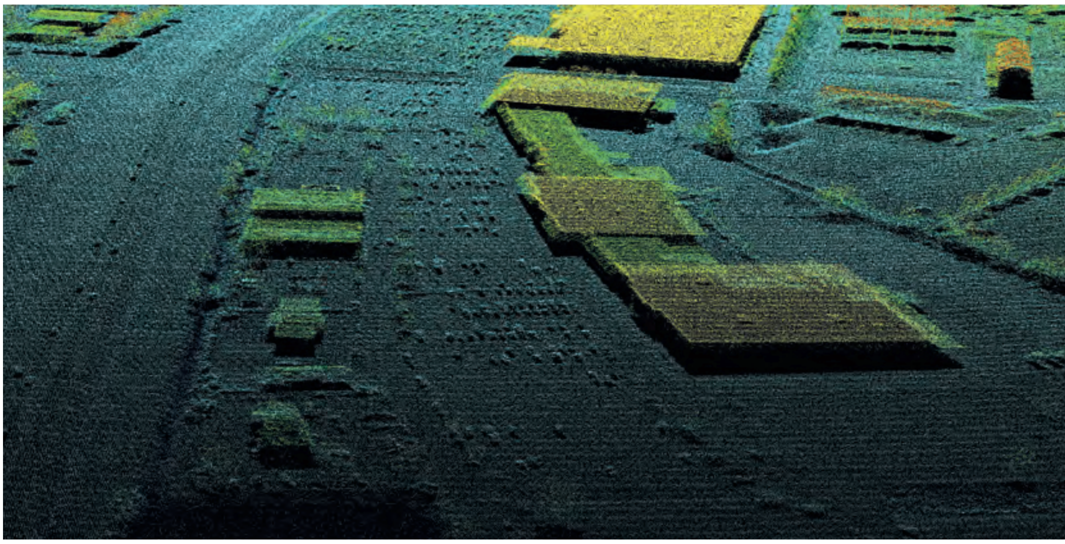
of the photons to the ground and back is measured individually. The amount of energy in each beamlet is much smaller compared to traditional Lidar but, thanks to the higher sensitivity, a single returning photon is sufficient to measure a range. The SPL system can generate 60,000 pulses per second. Since each pulse is split into 100 beamlets, this results in an effective pulse rate of 6.0MHz – significantly higher than can be achieved with linear-mode Lidar.



▲ *Figure 2, Point cloud of a single-pass survey with SPL at a height of 4,000m above ground level.*

MULTIPLE RETURNS

Linear-mode Lidar systems allow for the registration of peaks from various target reflections within the full return waveform, which can be processed to retrieve multiple returns. As SPL systems do not capture a continuous wave but count the individual photons instead, such a full waveform is not available. However, it is still possible to retrieve multiple returns thanks to the very short channel recovery times of 1.6 nanoseconds. This means that the photon counter is reset every 1.6 nanoseconds to count if any new photons returned from the beamlet. These are then regarded as a new return. The result is a true multi-return Lidar system with short inter-return separations of 24cm. As a result, SPLs can acquire high-density point clouds of 12 to 30 points per square metre with many returns underneath forest canopies. The point density varies inversely with the flying height. If the flying height is doubled, the covered swath will double, but the point density will be cut in half. An SPL instrument flying at 200 knots at 4,000m above ground will produce a point density of roughly 20 points per square metre. Figure 2 shows an example of a resulting point cloud.

APPLICATION AREAS

Linear-mode Lidar remains the industry standard, yet SPL is gaining acceptance for large mapping projects. For instance, the U.S. Geological Service 3D Elevation Program, which aims to systematically collect enhanced elevation data in the form of high-quality Lidar data, has employed SPL. The system has proven to meet the accuracy standard for USGS QL1 data, which corresponds to a height precision better than 10cm for non-vegetated areas. Other applications, such as corridor mapping, resource classifications and bathymetry, require more data from each data point, such as robust intensity values or full waveforms. These cannot be achieved with SPL, making linear-mode Lidar more appropriate.

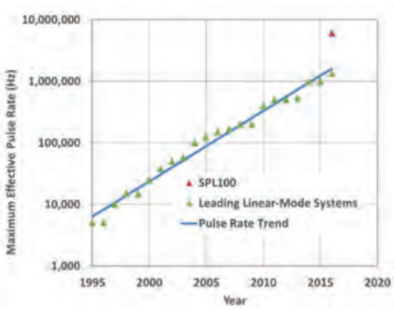
In general, the lower the cost per data point is, the greater the number of applications that will emerge to use any type of data. Therefore, SPL is particularly well suited to large-area applications where huge numbers of data points are to be acquired.

OUTLOOK

The performance of SPL is expected to increase over time in terms of accuracy and radiometric capabilities. This will result in a shift over time in application areas for which SPL is suitable. It is also expected that the effective pulse rate of SPL systems will continue to improve, just as effective the pulse rate for linear-mode systems has steadily improved over the past two decades. This can be seen in Figure 3. With current performance levels at six million points per second, SPL could potentially be capturing one billion points per second in less than a decade from now.

CONCLUDING REMARKS

Bringing down the cost per point through higher effective pulse rates is the best way to address large-area, high-point-density projects in the future. As the use of SPL becomes appropriate in more and more applications, we will see positive changes throughout industries, such as increased efficiency in resource management, more effective infrastructure planning and better preparation for natural disasters. ◀



▲ *Figure 3, Linear-mode Lidar productivity and the introduction of SPL.*

FURTHER READING

Swatantran, Anu; Tang, Hao; Barrett, Terence; DeCola, Phil; Dubayah, Ralph (2016): Rapid, High-Resolution Forest Structure and Terrain Mapping over Large Areas using Single Photon Lidar; *Scientific Reports* 6, http://www.nature.com/articles/srep28277

BIOGRAPHIES OF THE AUTHORS

Ron Roth is product manager for airborne topographic Lidar at Leica Geosystems. Roth holds a BSc in mechanical engineering from Worcester Polytechnic Institute and an MBA from Babson College. He was also awarded a United States patent for a remote counter-balancing mechanism.

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J. Marcos Sirota is president of the Sigma Space Corp. Sirota holds a degree in electrical engineering from the University of Buenos Aires and an MSc and PhD in aeronautics and astronautics from the University of Washington. He has received several technology awards from NASA for his work in Lidar.

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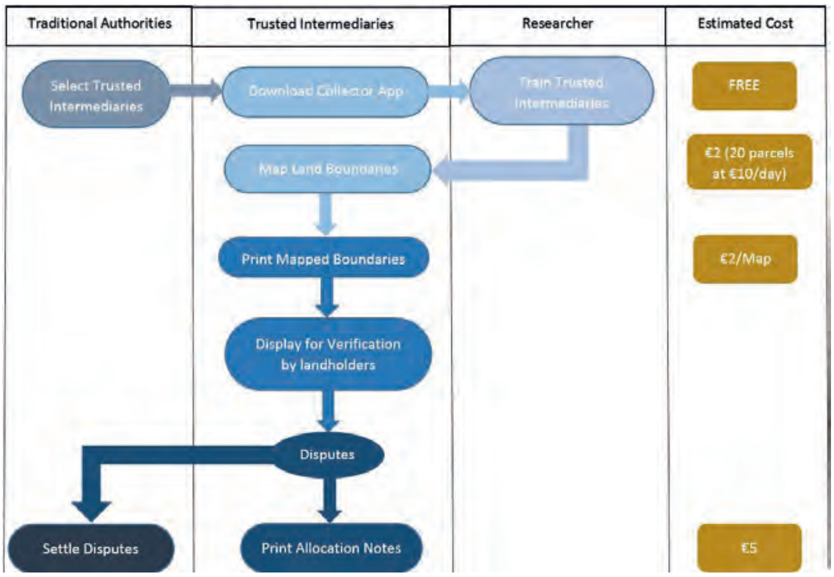
BY **KWABENA ASIAMA**, **ROHAN BENNETT** AND **JAAP ZEVENBERGEN**, UNIVERSITY OF TWENTE, ITC, THE NETHERLANDS

FITTING WITH THE LOCAL NEEDS

Customary Cadastres and Smartphone Surveys

The complex nature of customary land administration, coupled with slow, expensive and highly centralised national land registration systems, means the registration of customary land rights is oft neglected. Estimates suggest a mere 0.5% of Ghanaian customary land holdings are registered, making land grabbing in peri-urban areas easier and land management activities, such as land consolidation, highly impeded. This article shows the results of an experiment in which a smartphone app was used to enable a participatory, faster, cheaper and a more fit-for-purpose approach to rural customary land administration.



▲ *Figure 1, The mapping process and the costs incurred.*

▲ *Figure 2, Farmers and a trusted intermediary (holding the smartphone) are happy with the results.*

Ghana's customary lands account for 80% of the country's land parcels. They are usually managed by what are known as 'Traditional Authorities' (TAs). The majority of these TAs have successfully set up Customary Land Secretariats (CLSs) to manage land on their behalf. However, the rural CLSs have limited capacity to map land parcels. The costs of land surveys are high (not less than EUR500 per parcel for the complete process) and the surveyors themselves prefer to focus on more lucrative urban land mapping. The prevailing situation has resulted in CLSs seeking alternative ways to build up an appropriate land administration system (LAS).

As in other countries such as Kenya and Ethiopia, the use of orthophotos has been shown to be successful in mapping the urban areas of Ghana; visible boundary markers and fence walls mean the mapping process does not necessarily require excessive numbers of highly trained surveyors. In rural areas, however, general boundaries and temporary boundary markers are difficult to discern so there is a need for alternative ground survey methods – ones that are not as costly as conventional surveys based on total stations, chains/theodolites or high-precision GNSS. Promisingly, the registration laws of Ghana do provide for the use of general boundaries for first registration. Fixed boundaries are only necessary for subsequent registration and transactions, which opens up an opportunity for CLSs.

FIT-FOR-PURPOSE LAND ADMINISTRATION

Fit-for-purpose land administration is about building sustainable systems – within appropriate time frames, at minimal cost and at the required accuracy – that record a diversity of land rights. Smartphone usage is widespread in Africa, with a used Samsung Galaxy S2 (3G-enabled device) costing EUR25 in Ghana). As shown in articles in previous editions of GIM International (see 'Further reading'), this provides an opportunity for land administration: fusing the phone's GNSS functionality with a mapping app – and available imagery – creates a low-cost surveyor's toolkit. Esri's Collector for ArcGIS is freely downloadable ▶

i80

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  The ultra-rugged alloy cased i80 is the smallest and lightest receiver with dual hot swappable batteries, allowing continuous work and reduced user fatigue.

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- **TRACKING ALL SIGNALS AND SATELLITES**
  GPS, GLONASS, Galileo, Beidou, SBAS, QZSS;L1-L2-L2C-L5: every satellite and every signal tracked for the most reliable and accurate RTK solutions.

www.chcnav.com

(albeit with a subscription), providing a friendly environment for the geotech savvy. In addition, freely available satellite imagery from ESRI can be loaded in advance. The app allows for the recording of the land rights information in tandem with the collection of the spatial information, allowing for ease of information management.

LIVING THE EXPERIMENT

In the Northern Region of Ghana, in a place called Nanton, there is a real need to record information about land holdings. The need is driven by ideas to consolidate smaller land holdings into larger ones, and subsequently to improve agricultural output. With this in mind, in collaboration with the local TA, a test of a fit-for-purpose mapping approach using smartphones was set up by researchers from the University of Twente, ITC in a responsible 'living lab'-style arrangement in July 2016. For the TA, the aim was to obtain information about land holdings, whilst the research team sought to help the process, as well as to replicate and test the claims already made by Dyli, et al. (2016) in Ethiopia and Molendijk et al. (2015) in Columbia. Community involvement was paramount; the TA in the area was informed prior to the exercise and assisted in the site selection. Also with the help of the TA, two trusted intermediaries – staff of the CLS – were selected and trained in the use of the app. A Worldview-1 satellite image of the area from February 2016 was also acquired from DigitalGlobe Foundation and was printed out to be used for visual support for, and validation of, the data collected using the ground methods. The stream feature of the Collector app was used to enable the data to be collected automatically as the trusted intermediaries walked the perimeter with the farmers. This was done for each parcel within the area of interest. At the end of the ten-day experiment, 200 farm parcel boundaries had been mapped and verified by the team.

▲ *Figure 3, The mobile app interface.*

RESULTS AND REACTION

The involvement of the community is paramount to the adoption of new technology, to allow for its use without the involvement of the researcher – or a fully licensed surveyor. The approach used in this experiment was a hands-off one; the farmers and the trusted intermediaries undertook the mapping on their own. The CLS staff and the farmers found the app to be very user friendly and the TA showed interest in adopting it to supplement its land administration system (which currently comprises land-rights information but no spatial information). Given the slow and expensive conventional land survey methods, the TA regards this process as offering an alternative way for its CLS to secure the land rights. This approach is comparatively faster at an estimated EUR9 per parcel and is flexible enough to incorporate the different levels of customary land rights. On the part of the farmers, it also serves as a check of the size of their farms to determine the quality of inputs ideally needed. The information is stored in the cloud and updates can be effected by the farmers themselves, with the approval of the CLS.

CONCLUDING REMARKS

This app shows much promise as it will serve as an initial step towards a faster, cheaper and trustworthy approach to registration of the rural customary lands. The use of smartphones, which are widely available in Africa, provides a unique opportunity as a fit-for-purpose process is possible without the need for a CLS to acquire extra equipment. Furthermore, while the approach used by conventional surveyors only registers the coordinates of the corners of land boundaries, this approach is suitable for mapping irregularly shaped farmlands.

ACKNOWLEDGEMENT

The authors wish to thank DigitalGlobe Foundation for their support. ◀

FURTHER READING

Dyli, J., Bennett, R. M., & Martinez, J. A. (2016, August). Apps for Land Administration: Exploring the Needs, Options and Future Developments. *GIM International*, 33–35. Retrieved from https://www.gim-international.com/magazine/august-2016

Lemmen, C., Bennett, R., McLaren, R., & Enemark, S. (2015, January). A New Era in Land Administration Emerges. *GIM International*. Retrieved from https://www.gim-international.com/content/article/a-new-era-in-land-administration-emerges

Molendijk, M., Morales, J., & Lemmen, C. (2015). Light Mobile Collection Tools for Land Administration. *GIM International*. Retrieved from http://www.gim-international.com/content/article/light-mobile-collection-tools-for-land-administration

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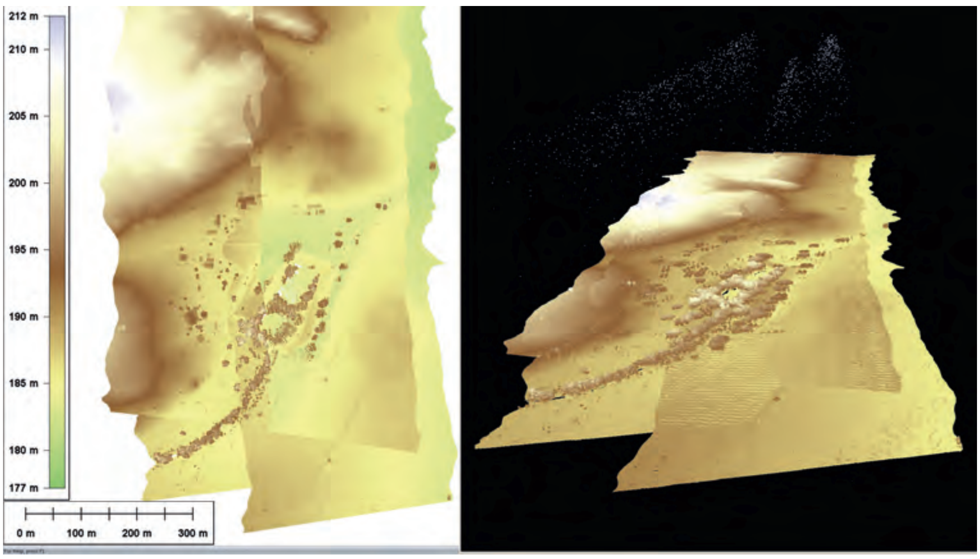
BAYESMAP SOLUTIONS

Extracting More Value from **Lidar Data**

The company BayesMap Solutions was established in October 2014 with the objective to provide unique consulting and software development services for the airborne Lidar industry. The main focus is data processing, providing fast and effective solutions to challenging problems. The company helps clients extract a maximum of information from large and complex datasets and to significantly increase the accuracy of data and derived products.

BayesMap Solutions was founded by André Jalobeanu, who obtained a PhD in image processing from INRIA Sophia Antipolis, France. Before starting BayesMap, he worked as a research scientist in France and Portugal, and then as a research fellow at the Naval Postgraduate School in Monterey, USA. He has been doing research in data processing and analysis (images, signals, time series and point clouds) for more than 15 years, including in Lidar for the past six years. The methods he developed all use Bayesian inference, with an emphasis on automation and uncertainty estimation.
In a Bayesian framework, rigorous sensor modelling combined with expert knowledge leads to optimal solutions, which can be point clouds, geometric parameters or elevation models depending on the needs. Probabilistic modelling enables the user to obtain something new: uncertainty attributes and spatial accuracy maps. This is achieved by propagating errors from input to end result. All data sources are combined in a consistent way and automatically weighted by the software, avoiding arbitrary cuts and losses and costly user interaction.

André Jalobeanu decided to start BayesMap to apply these concepts and recent research results to the Lidar mapping industry. In the early days, the first clients purchased consulting services to have strip alignment done using prototype BayesStripAlign software. Due to high demand, this package was the first to be developed (despite extensive experience with waveforms). Production-ready BayesWavEx followed one year later, offering vendor-neutral point cloud extraction from LAS 1.3 waveforms.



▲ *BayesStripAlign for an extreme case. Non-optimised data, RIEGL LMS-Q560 airborne scanner, captured during a collaborative project with Bush Heritage Australia at Boolcoomatta Station near Broken Hill, NSW, Australia. Left: plan view of the point cloud; right: 3D rendering coloured by elevation (image courtesy Airborne Research Australia/ARA).*

CURRENT PROFILE

BayesMap Solutions is a limited liability company (LLC), now based out of Pleasanton, California, USA. It is managed and operated by the founder, who is also the software engineer. Technical support is provided by the software developer (same day with a fast-lane production licence). BayesMap uses a client-centred approach to product design and development. The small size of the company allows for great flexibility, enabling client requests to be handled and new capabilities to be implemented in a short time. The company offers discounts depending on the client's corporate social responsibility statement and 'green' engagement. Academic pricing is available for research institutions.

The main business is software and consulting, with a focus on improving data quality and helping clients to reduce collection costs. While it started with traditional airborne Lidar, the company now also provides geometric correction for unmanned aerial vehicle (UAV) sensors, which often follow a more complex trajectory than large aircraft. Increasing the performance and reliability of software products is a priority, through algorithmic development and code optimisation as well as constant feedback from users. All packages are independent, use a simple yet powerful command-line interface and come with a free 30-day evaluation period and full support.

Many people are frustrated with money-wasting practices such as flight-line edge cutting, flying low and calibration lines. At BayesMap, the power of Bayesian inference is leveraged to make the best use of all available data without throwing away anything useful. This approach allows BayesMap to fly higher and still get high-quality results, thus reducing collection costs. And to use only regular flight lines for sensor calibration.

GLOBAL SCOPE

The target markets are mainly airborne Lidar data providers, systems builders and research institutions from all countries. Current clients are located in France, Germany, Australia, Canada and the USA. A simple licence management scheme allows the rapid set-up of node-locked trial and paid licences via email, after an EULA is signed electronically via PandaDoc. Support is also provided by email, within one or two business days for production, depending on the licence tier. Quick to install (no dependencies) and compatible with 64-bit OS (Windows, MacOS), the software packages are simple to use for those familiar with LAStools. As the main input is raw data, or uncorrected georeferenced point clouds (billions of waveforms or points), having the software in the same location as the data saves time. This is why BayesMap does not currently provide cloud solutions.

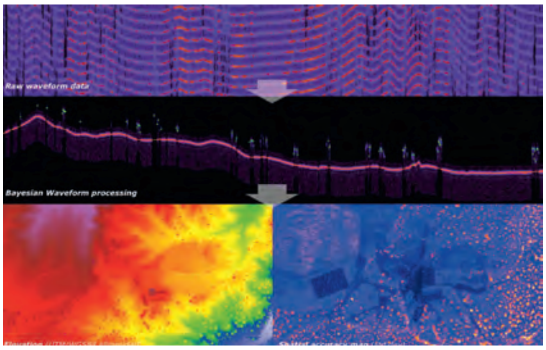
THE COMPANY OFFERS THE FOLLOWING SOFTWARE PACKAGES:

- BayesStripAlign 2.0: automatic point cloud registration, geometric correction, quality control – this is BayesMap's flagship product.
- BayesWavEx 1.0: waveform processing with original attribute extraction such as range uncertainty and target thickness, removes detector artefacts, robust to overlaps.
- BayesCloudChange (under development): automatic detection of significant changes between point clouds (vertical differences and horizontal displacements).
- BayesAccuGrid and other, smaller packages, planned: 3D surface reconstruction with error propagation, de-noising and other features, depending on demand.

LOOKING AHEAD

The main objectives of the company in the near future are as follows:

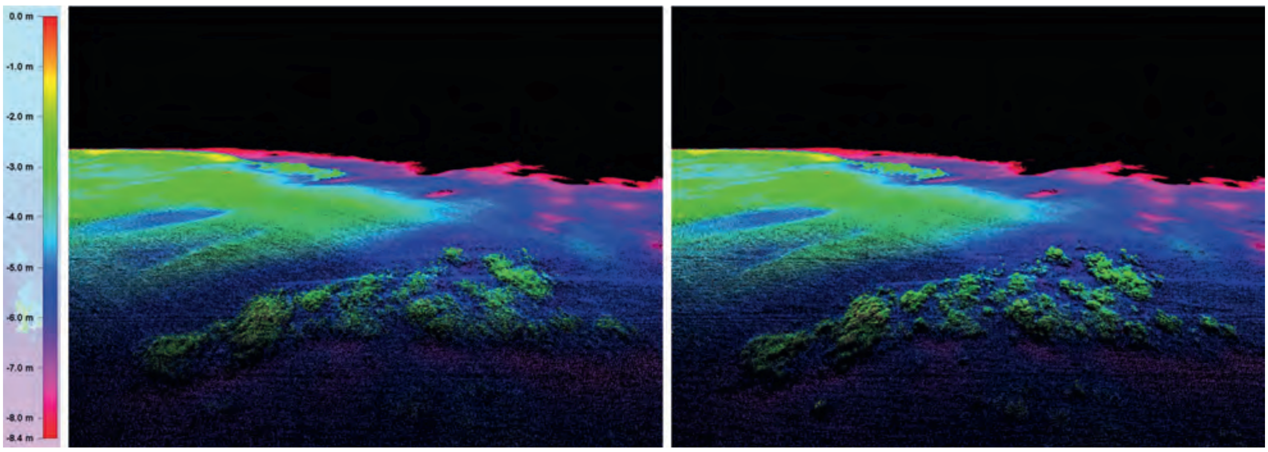
- To develop research-grade science to serve efficient problem-solving. To continue its research and development efforts to meet ever-more demanding client needs and adapt available tools to new sensors such as photon-counting and bathymetric scanners. To develop new algorithms to tackle complex topology arising in terrestrial and close-range scans.
- To strive for enhanced accessibility through graphical user interface design, allowing users who are unfamiliar with command lines to immediately use all the functionalities.
- To propose workshops and training sessions within professional meetings or directly with the client.
- To contribute to brain-storming over data formats, e.g. to include range or point uncertainty in final data products. BayesWavEx already computes range uncertainty and stores it thanks to extra LAS attributes, enabling rigorous error propagation to derived products such as elevation models.
- To start hiring to enhance client-training capabilities, deal with the increase in support requirements and help develop B2B and product sales.



Waveform data processing with BayesWavEx extracts a maximum number of returns in a robust way, despite contamination by noise, sensor artefacts and low vegetation. Middle: typical waveform; bottom: derived elevation model (left) and spatial accuracy map (right).

More information
bayesmap.com

Every month *GIM International* gives a company the opportunity to introduce itself in these pages. The resulting article, entitled Company's View, is subject to the usual copy editing procedures, but the publisher takes no responsibility for the content and the views expressed are not necessarily those of the magazine.



3D view of a point cloud from a RIEGL VQ-820-G topobathymetric Lidar showing the underwater landscape of parts of Ningaloo Reef along the northwestern coast of Australia. Depicted are combined point clouds from multiple overpasses. Left: original; right: processed with BayesStripAlign. Underwater structures are much better defined after strip alignment. See also Pushing Lidar to the Limits (page 29-31) in this issue. Image courtesy ARA).

Further Standardisation in Land Administration

The Open Geospatial Consortium (OGC) has set up a Domain Group on Land Administration. OGC has long-standing liaisons with major players in the land administration domain, including the International Federation of Surveyors, the Technical Committee 211 of the ISO, the Royal Institute of Chartered Surveyors, the World Wide Web Consortium, OASIS and the Global Land Tool Network. OGC always strives to use, build on and complement existing standards. However, while there are some standards describing elements of an administrative system, such as in the Land Administration Domain Model (LADM), there might be gaps in the way that they incorporate geospatial descriptions of land records and/or there might be inadequate rules for defining and describing the quality of the records. The LADM was initiated by FIG. During the World Bank Conference on Land and Poverty – to be held from 20-24 March 2017 in Washington DC, USA – the subject of standardisation in land administration will be a topic of discussion.

ANNUAL AFRICA REGIONAL NETWORK (ARN) CAPACITY DEVELOPMENT WORKSHOP

From 17-18 November 2016, Vice President Diane Dumashie chaired the Africa FIG Regional Network (ARN) 2016 meeting and facilitated the training workshop. The workshop was attended by 35 land professionals. The theme, 'Ensuring good land governance practices in the land profession and what you can do about it', appealed to those wishing to gain an understanding of the international land governance initiatives, specifically the Voluntary Guidelines on the Responsible Governance of Tenure (VGGTs). The workshop focus was to:

- Build future resilience into land professional practices to improve governance of tenure
- Understand the implementation opportunities referenced in the VGGTs
- Ensure that people benefit from secure and equitable tenure rights.

The workshop was implemented with the traditional highly participatory design and fast pace that enabled the participants to gain an overview of, discover principles and practices, and then to design, develop and communicate key good governance messages, including by capturing their ideas in video clips.

More information
www.fig.net

A Message from GSDI's New President

As Dave Lovell takes over the baton from Dave Coleman as GSDI's president for the coming year, he reflects here on the opportunity.

GSDI has existed for 20 years. During that time, the association has made nearly a quarter of a million US dollars available to support SDI developments with small grants. We have arranged conferences around the world in which knowledge and experience has been exchanged and inspiration and energy has been stimulated.

Over the years, a lot has been achieved in the development and deployment of spatial data infrastructures (SDIs), but while much has been achieved, there is much more that needs to be done to realise the GSDI vision of 'a world where everyone can readily discover, access and apply geographic information to improve their daily lives'.

Many more small grants are needed to stimulate SDIs, from the bottom up, particularly in the developing nations, to complement and support the work of the Group on Earth Observations (GEO), United Nations Global Geospatial Information Management (UN-GGIM) and others working top-down. More opportunities for gatherings are needed where academics, industry and policymakers from different countries, different domains and different communities interact to help drive SDIs forward.

It is the people who are developing technical capability – the people who are applying technical capability that we must harness for a common purpose of making everything location-enabled. Yet people organise themselves into natural communities – communities of surveyors, of programmers, of engineers, of medics, and so on. From this we can conclude that, while GSDI through its members and sponsors has delivered a lot in the past and will continue to do so in the future, we will deliver even more, even faster when we work in and with other communities of interest.

I am pleased that the United Nations Economic and Social Council and three of the UN-GGIM regional committees have already recognised the valuable contribution which GSDI has made and will continue to make to 'the agenda for the development of global geospatial information and its use to address key global challenges'. We have also worked, and will continue to work, with the Group on Earth Observations.

In the coming period, we intend to develop more and closer relationships with these and other bodies to deliver a programme of capacity development and knowledge exchange in order to develop and deploy more and better spatial data infrastructures to address some of society's most pressing challenges.

More information
www.gsdi.org

▲ New president Dave Lovell.

Journal of Geodesy Celebrates 90^{th} Volume

In 1995, the *Journal of Geodesy* replaced the previous IAG journals *Bulletin Géodésique* and *Manuscripta Geodaetica*, continuing as the IAG's official journal. In 2016, the *Journal of Geodesy* issued its Volume 90, having published many articles by the most respected geodesists.

At the meeting of the Section of Geodesy during the first IUGG General Assembly in Rome from 2-10 May 1922, a journal devoted exclusively to geodetic science and connected to the section was suggested. Apparently, the name 'Journal of Geodesy' was even suggested by William Bowie in the run-up to the meeting. Organisational issues, statutes and summaries from the meeting were later collected in Volume 1 (published under the title *Conseil International de Recherches, Union Geodesique et Geophysique international, Section de Geodesie, Premiere Assemble Generale, Rome, Mai 1922)* and Volume 2 (with a number of scientific articles already included as Annexes) of *Bulletin Géodésique* (BG). Beginning in 1924 (renumbered to Volume 1), BG was published four times a year, with the exception of the WWII years: 1943, 1944 and 1945. The first issue of *Manuscripta Geodaetica* (MG) appeared in 1976, dedicated to publishing papers of a more theoretical or computational nature that were considered too long for BG. Like BG, MG became an IAG journal. In 1995 the chief editors Christian Tscherning and Petr Vanicek decided to merge the two journals, and in their farewell editorial column they introduced the new *Journal of Geodesy.*

Today, an ever-growing community of scientists from all around the world publish exciting new results in the *Journal of Geodesy* (JG). The current Editorial Board, elected in 2015, is committed to the publication of high-quality papers. The JG is abstracted/indexed in the Science Citation Index (SCI) and many other databases, and it continues to have the highest impact factor of the geodetic journals listed in the SCI.

Jürgen Kusche

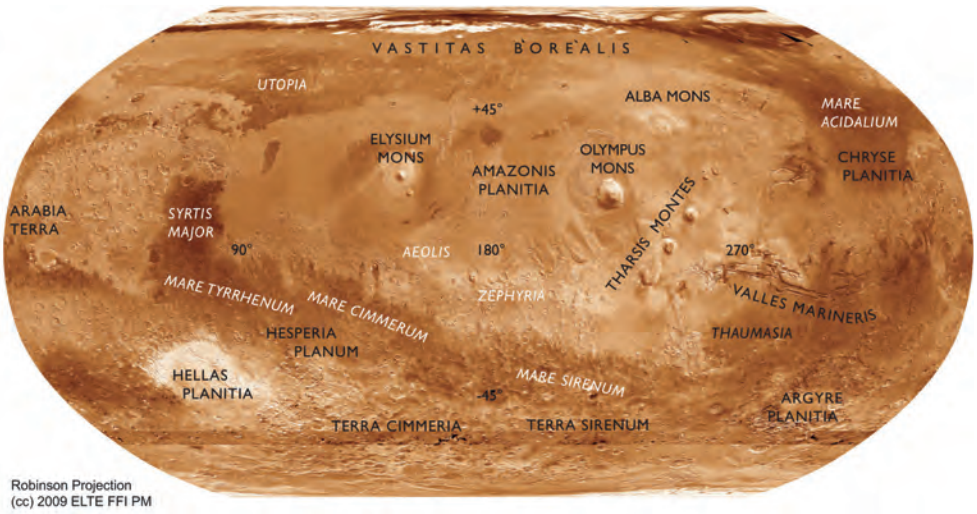
Journal of Geodesy:
http://link.springer.com/journal/190

More information
www.iag-aig.org
http://gghs2016.com

Mapping out of This World

The ICA Commission on Planetary Cartography (https://planetcarto.wordpress.com/) has been productive and innovative for many years, and its work, along with other issues related to extra-terrestrial mapping, is reported in its regular blog. Current leadership of the commission follows a US/Russia model which has characterised its work since its inception in 1999. Co-chairs are Henrik Hargitai, working out of the NASA Ames Research Center in California, and Irina Petrovna Karachevtseva, attached to the Moscow University of Geodesy and Cartography.

In addition to general aims related to scientific research, the commission has focused recently on a) the compilation of the Integrated Database of Planetary Features to be used by the community in producing new planetary maps, from mission planning to outreach; b) the promotion and documentation of planetary cartographic products via the website and the Digital Museum of Planetary Mapping; c) the



▲ **Albedo of Mars. (courtesy H. Hargitai)**

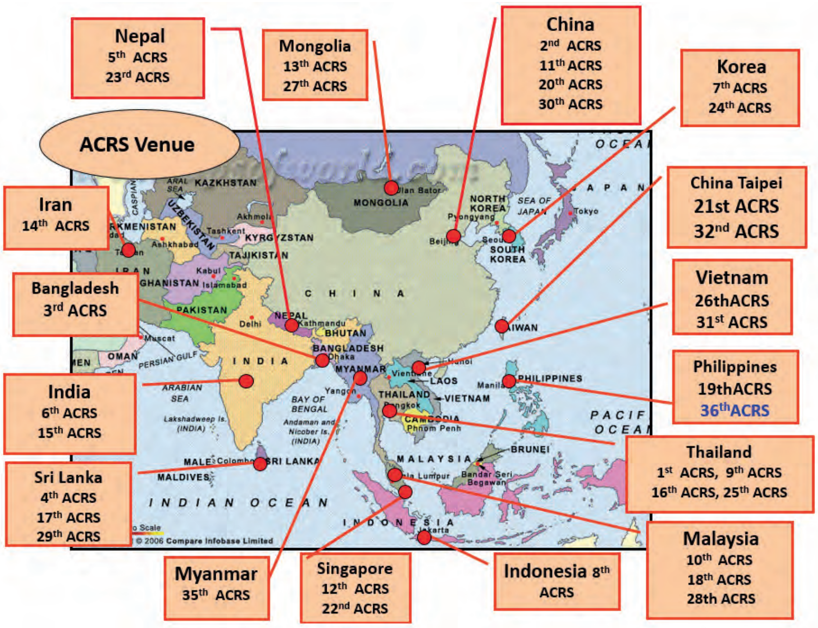
production of the Planetary Maps for Children series (in different languages) and d) the production of online course materials in planetary mapping.
The Digital Museum available at (https://planetarymapping.wordpress.com/) is a comprehensive and continually developing record of human endeavours and creativity in surveying and mapping our neighbouring planets and other celestial bodies. Categorised by year and also by subject, this provides a visual archive of our fascination with our solar system and the skies above.
At a different level, and ensuring that new generations are equally enthused, the development of planetary maps for children is also of interest. Most recently, at the American Geophysical Union congress in San Francisco in December 2016, the commission launched the new children's map of Pluto and its largest moon, Charon. This is the newest product from the impressive range of children-oriented planetary maps (available at https://childrensmaps.wordpress.com/). This resource allows for maps to be viewed directly online, downloaded for printing, or ordered. Planetary globes can be downloaded for application in Google Earth. International, multilingual versions of the website and many products are also available, and there are descriptive accounts of the mapping process and the role of place names in particular.
The work of this commission is of widespread interest – geomatics in action across the universe!

More information
www.icaci.org

Review of the 37th Asian Conference on Remote Sensing (ACRS)

The 37th Asian Conference on Remote Sensing (ACRS) was successfully held from 17-21 October 2016 in Colombo, Sri Lanka, with 764 participants from 31 countries and regions. The conference was co-organised by the Asian Association on Remote Sensing (AARS) and the Local Organising Committee (LOC) of Sri Lanka. At the opening ceremony, Emeritus Professor Shunji Murai, former president of ISPRS, received the Chen Shupeng Award for his long-time contribution to ACRS/AARS as one of the founders. A total of 398 technical papers, 314 orals and 84 posters were presented at the conference. Various themes including satellite programmes, image processing algorithms, land use change, disaster, Lidar, SAR, UAVs, etc., were actively discussed during the conference.

Reflecting the fact that ACRS and ISPRS are sister organisations, the ISPRS Council Meetings with technical commission presidents (TCPs) were held during ACRS at the same venue. It was our great honour to have an opening address from ISPRS President Prof Christian Heipke and to have all the ISPRS council members and TCPs attending the opening ceremony. The ISPRS Special Session was organised on the second day, and Prof Heipke and all the TCPs explained the outline of ISPRS and each technical commission (TC). This was a good opportunity for ACRS participants to learn more about ISPRS and each TC.



▲ ACRS venues over the years.

Supporting students and young scientists is one of the most important objectives of ACRS. We do not discriminate against student papers in any way, and we have various awards and events to promote the younger generation. The number of students and young scientists attending ACRS continues to increase. Since 2010, in cooperation with ISPRS, we have been organising the annual Student Summer School (SS) just after ACRS, which has significantly helped to give students from the region opportunities to learn more about remote sensing. In this respect, I would like to thank ISPRS for their kind support.

The 38th ACRS will take place from 23-27 October 2017 in New Delhi, India. We welcome your active participation.

Kohei Cho
General secretary of AARS

More information
www.isprs.org

2017

FEBRUARY

OLDENBURGER 3D-TAGE
Oldenburg, Germany
from 1-2 February
For more information:
http://bit.ly/2iiokek

ILMF 2017
Denver, USA
from 13-15 February
For more information:
www.lidarmap.org

APRIL

GIS-FORUM
Moscow, Russia
from 19-21 April
For more information:
www.gisforum.ru/en

GISTAM 2017
Porto, Portugal
from 27-28 April
For more information:
www.gistam.org/?y=2017

MAY

XPONENTIAL 2017
Dallas, USA
from 8-11 May
For more information:
www.xponential.org/xponential2017

GEO BUSINESS 2017
London, UK
from 23-24 May
For more information:
http://geobusinessshow.com

FIG WORKING WEEK 2017
Helsinki, Finland
from 29 May - 2 June
For more information:
www.fig.net/fig2017

JULY

INTERNATIONAL CARTOGRAPHIC CONFERENCE
Washington, USA
from 2-7 July
For more information:
icc2017.org

ESRI USER CONFERENCE
San Diego, USA
from 10-14 July
For more information:
www.esri.com/events/user-conference

SEPTEMBER

UAV-G 2017
Bonn, Germany
from 4-7 September
For more information:
uavg17.ipb.uni-bonn.de

ISPRS GEOSPATIAL WEEK
Wuhan, China
from 18-22 September
For more information:
zhuanti.3snews.net/2016/ISPRS

INTERGEO
Berlin, Germany
from 26-28 September
for more information:
www.intergeo.de

CALENDAR NOTICES

Please send notices at least 3 months before the event date to: Trea Fledderus, marketing assistant, email: trea.fledderus@geomares.nl

For extended information on the shows mentioned on this page, see our website: www.gim-international.com.