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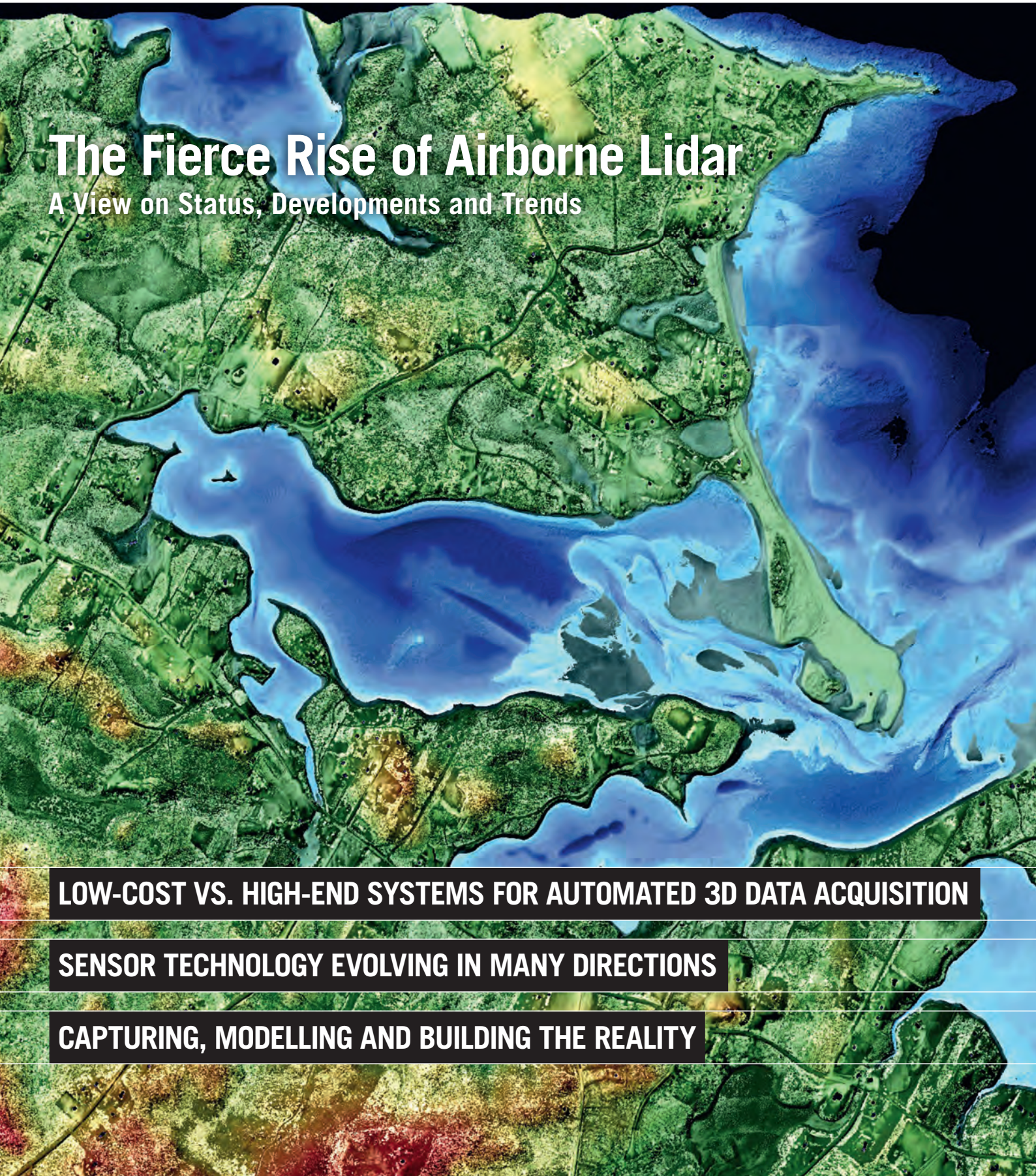

The Fierce Rise of Airborne Lidar

A View on Status, Developments and Trends

LOW-COST VS. HIGH-END SYSTEMS FOR AUTOMATED 3D DATA ACQUISITION

SENSOR TECHNOLOGY EVOLVING IN MANY DIRECTIONS

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This issue is focused on laser scanning, both airborne and terrestrial. The first commercial airborne Lidar systems appeared on the market in the mid-1990s. Since then this active remote-sensing technology has evolved rapidly. An article on this subject from page 12 onwards provides an overview of the main technological advances of today's operational systems. (Image courtesy: Nova Scotia Community College).

GIM INTERNATIONAL

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The Power of Data

As I write this we are at the very start of the new year, 2017. The January issue is traditionally published a little later in the month, taking account of the fact that many of our readers enjoy well-deserved holidays over the festive period. By now, most of you have probably started work again. Ahead of you lies another year full of challenges, new technologies and both foreseen and unforeseen developments in your personal as well as professional life. I would like to especially highlight one trend, which is both a challenge and a development, and that is 'the power of data'. In the November 2016 issue of *GIM International* Professor Stig Enemark, one of the respected members of *GIM International's* Editorial Advisory Board and a regular contributor, wrote an Insider's View column on 'The Call for a Data Revolution'. Just a few weeks later I witnessed Professor Enemark receive the Michael Barrett Award at RICS in London. In his lecture called 'Land Governance in Support of the 2030 Global Agenda' to mark that occasion, he highlighted the importance of good land governance to comply with the global agenda of the Sustainable Development Goals (SDGs) by 2030, in order to build a sustainable long-term future. The growing relevance of data in facilitating good land governance is unmistakable. Land professionals must also be aware of this growing relevance, and new land administration systems are necessary to deliver good data for governments to base their policies upon if the SDGs are to be achieved. This month the first UN World Data Forum is being held in Cape Town, South Africa (from 15-18 January). The UN World Data Forum is an outcome of the main recommendations of the 2014 report titled *A World that Counts*. The UN Statistical Commission has stepped up to organise this forum which will indeed intensify cooperation between various professional groups, such as information technologists, geospatial information managers, data scientists and users as well as civil society stakeholders. The event will have the overarching theme of 'Harnessing the Power of Data for Sustainable Development' and will include sessions on data literacy, geospatial and remote sensing data for sustainable development applications, the role of open data to support national statistics and monitoring against the SDGs, and big data innovations. This high-level forum will certainly help the year of data to start with a bang! We'll definitely keep you updated on all the outcomes of the UN World Data Forum, plus we'll monitor and report on the ever-increasing role of data in the daily life of geomatics professionals – all in order to give you the best possible head start in harnessing the power of data. For now, let me end this month's column by wishing you a happy, healthy and prosperous New Year!

▲ *Durk Haarsma, publishing director*

Retaining Our Global Values

The political events of the past six months will potentially have a significant impact on land professionals worldwide. The decision of the UK (apart from Scotland) to exit the European Union and the election of a right-wing president in the USA show worrying trends indicating that globalisation, open movement of services and, most importantly, international humanitarian and development funding are under threat. This has sent shockwaves through NGOs and others who fear the impact on the world's largest donor of international humanitarian and development funding. The future direction of the World Bank and the U.S. Agency for International Development (USAID) are uncertain, for example. The wall was torn down in Berlin 27 years ago. The question now is whether barriers are starting to be erected again that will stop solutions to global issues which will impact us all.

Solutions to the overall global land issues relate to alleviation of poverty, improvement of social inclusion and stability, investments and economic development, and environmental protection and natural resource management. These land matters are now embedded in the Sustainable Development Goals (SDGs) that form a blueprint for a sustainable future agreed on by all world leaders. This agenda cannot be achieved without having good land governance in place – including the operational component of land administration systems.

▲ *Robin McLaren.*

As some countries turn inward and ignore the global challenges of the 21st century, it is essential that land professionals refocus and re-energise their efforts towards more effectively communicating and resolving global land issues. Just as advocates of free markets and globalisation have failed to convince many citizens of the benefits of this approach, land professionals must not be complacent. They need to rethink and reshape their message, providing clearer evidence to politicians of the benefits of their land interventions and investments.

Land professionals have been guilty of designing and implementing land administration solutions that are inappropriate and non-sustainable for developing countries. Members of the family of UN agencies provide mixed messages to developing countries, confusing recipients of aid in the land sector. For example, the concept of 'continuum of land rights' is not universally agreed and advocated. Global land issues require multi-disciplinary solutions, but professional silos have significantly limited the effectiveness of the solutions. The key stakeholders in the land sector also need to attract new technology partners to provide truly scalable solutions, such as Facebook which is actively mapping settlements across Africa to prioritise the provision of internet services. Our engagement strategy has been ineffective at communicating with politicians and key decision-makers. Technical rather than socio-economic messages prevail and land rarely sits at the top table.

Within the context of the recent political shift to build walls and walk away from global responsibilities, it is time for land professionals to take stock. This challenge provides an opportunity for land professionals to rethink their strategy for coordinating, designing, communicating and resolving global land issues. The land issues must not be sidelined and land professionals need to retain their global perspective and values. This new SDG agenda presents a historic and unprecedented opportunity to bring the countries and citizens of the world together to decide and embark on new paths to improve the lives of people everywhere.

Intel Acquires UAV Manufacturer MAVinci

Intel has acquired MAVinci, a start-up from one of ESA's business incubators in Germany that has developed an easy-to-use system for land surveillance. Anil Nanduri, head of Intel's drone business, said that MAVinci focuses on precision payloads for construction and inspections. They have best-in-class mission planning software for terrain mapping, enabling very quick creation of a mission for a specific job. The company will work with Ascending Technologies, also acquired by Intel, to expand Intel's business with commercial customers in agriculture, insurance, construction and mining. Ascending Technologies develops artificial intelligence for unmanned aerial vehicles (UAVs) to avoid collisions.

▸ http://bit.ly/2hCOFGy

MAVinci Sirius.

MicroSurvey and Pix4D Announce Partnership

Michael Bachinski and Lorenzo Martelletti.

MicroSurvey and Pix4D have entered into a global partnership which will provide end-to-end solutions to a wide range of customers. By combining products and competencies, the companies bring expert solutions to customers adopting unmanned aerial vehicle (UAV) and photogrammetry technology. Focusing primarily on forensic accident and crime scene investigation, Pix4D and MicroSurvey will create software bundles for complete solutions, enabling field-to-office workflows for anyone using photogrammetry. The combined solutions for both forensic and land surveying markets will be available online and through existing MicroSurvey distribution channels.

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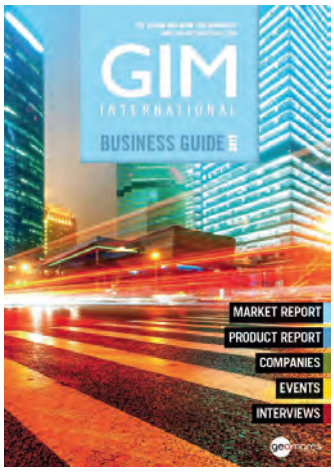


GIM International *Business Guide 2017.*

The team at *GIM International* is currently putting the finishing touches to one of its most important issues of the year: the annual Business Guide. The 2017 edition of the Business Guide will provide valuable insights into the current state of the geomatics market and associated industries.
One key article in the Business Guide 2017 is a report based on the findings from a market survey, providing a unique perspective on the future direction of the geomatics business. This comprehensive publication additionally includes five in-depth articles, each exclusively written for *GIM International*, zooming in on the very latest trends and developments in the application of geomatics-based surveying technologies in the following five fields: agriculture, construction & infrastructure, heritage mapping, land administration and mining. The articles cover the topics of both data gathering and data processing.

http://bit.ly/2iaaavn

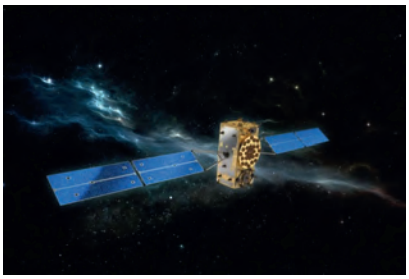
City of Helsinki Advances 3D City Initiative

Helsinki 3D city model.

The city of Helsinki in Finland is midway through an initiative to capture the city and create a new 3D city model that is scheduled to be completed in 2017. Helsinki has a long tradition of 3D city modelling, dating back to the 1980s. Helsinki wanted to update its current 3D city model with new, innovative applications that could provide entire city modelling capabilities in order to improve its internal services, promote smart city development and share data through an open format for citizens and other agencies. Helsinki also wanted to create a pilot portfolio to showcase the power of reality modelling in coordination with local universities to generate interest in academic organisations. This EUR1 million project used Bentley applications to encourage commercial research and development and public engagement. For example, the city used Bentley Map to create accurate base maps and to geocoordinate utility networks.

http://bit.ly/2hIEGCB

Europe's Satellite Navigation System Galileo Goes Live



Europe's own Galileo satellite navigation system has begun operating, with the satellites in space delivering positioning, navigation and timing information to users around the globe. The European Commission, owner of the system, formally announced the start of Galileo Initial Services, the first step towards full operational capability. Further launches will continue to build the satellite constellation, which will gradually improve the system performance and availability worldwide. ESA has overseen the design and deployment of Galileo on behalf of the Commission, with system operations and service provision due to be entrusted to the European Global Navigation Satellite System Agency next year. After five years of launches there are now 18 satellites in orbit. The most recent four, launched November 2016, are undergoing testing ahead of joining the constellation in the spring. The full Galileo constellation will consist of 24 satellites plus orbital spares, intended to prevent any interruption in service.

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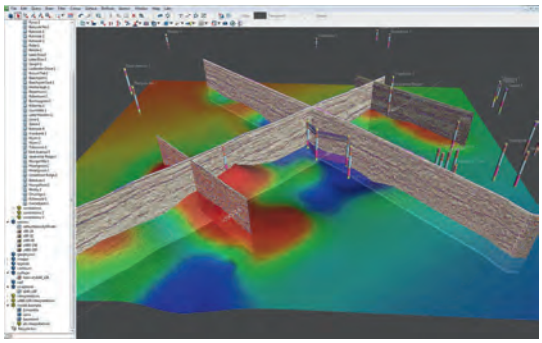
Maptek Software Used for Prestigious Infrastructure Project in Qatar



Maptek Eureka.

Eureka modelling software from 3D visualisation technology developer Maptek is being applied to the construction of a multi-billion-dollar transport infrastructure project in Qatar. The infrastructure project, managed by Qatar Rail, will create a rapid transit network consisting of light rail, the metro system and high-speed trains between Qatar and Saudi Arabia. Qatar Rail uses Eureka to view, analyse and model regional geological and GIS data. Eureka modelling and analysis tools allow the investigation of critical aspects in relation to the conditions underground and structures to be erected, said Marin Griguta, director of civil works in the QIRP Department at Qatar Rail. Within Eureka, data is amassed into a single, spatially coordinated database for creating detailed 3D geological and geotechnical structures – key for the planning of viable construction routes.

http://bit.ly/2gWwQ1k

Sensor Technology Evolving in Many Directions

5 Questions to... Michel Stanier

As Lidar is a hot topic in the geomatics industry with numerous fields of applications, *GIM International* decided to ask Michel Stanier, chief operating officer of Teledyne Optech, to answer five questions in the context of airborne Lidar.

Lidar has been developing rapidly over the last couple of years. Can you give us an update?

Indeed, airborne Lidar is developing rapidly in several directions. The unmanned aerial system (UAS)/remotely piloted aircraft system (RPAS) platforms are driving a continued reduction in sensor size, weight and power. However, for commercial data providers, the primary focus remains on collection efficiency and lower operating costs to increase competitiveness. Teledyne Optech has led the charge by developing unique, innovative solutions such as SwathTRAK's adaptive field of view (FOV), which eliminates the inherent inefficiency of fixed-FOV sensors in changing terrain elevations. The net result is a sharp reduction in flight/processing time and a constant point density even in highly variable terrain. We are continuing to push the efficiency envelope with more major improvements to our Galaxy platform, the most compact and versatile sensor in the marketplace.

Other significant Lidar developments we have pioneered are the Eclipse – the first low-cost, autonomous sensor – and the Titan, which is the first multi-wavelength, multi-application sensor. The Eclipse is the ideal entry-level sensor for data collection up to 3,000 feet, whereas the Titan supports numerous applications – simultaneous high-resolution topography and/or bathymetry and enhanced classification capability – in a single-sensor configuration, letting service providers differentiate and grow their addressable market.

What are the most relevant applications of your products?

We see two distinct Lidar sensor categories. The first category is one of generalist sensors that offer flexibility and diverse applications, enabling different project types with a single sensor investment. This includes our Galaxy, a high-performance mapping sensor that delivers unparalleled collection efficiency for wide-area mapping projects, but is also excellent for low-altitude, high-precision corridor work from smaller platforms thanks to its compact size and variable power feature. The multispectral Titan is another generalist sensor that can handle high-resolution topographic and bathymetric surveys simultaneously. Finally, our new Polaris terrestrial laser scanner (TLS) doubles as a high-speed indoor scanner for building information modelling (BIM) initiatives and a long-range outdoor scanner for geomorphic hazards or infrastructure mapping. The second category is one of application-specific sensors such as the Eclipse – totally autonomous mapping Lidar used primarily for corridor and small-area surveys on smaller platforms.

One promising recent advancement for mapping applications is photon Lidar (also known as Geiger-mode Lidar). What are your expectations for this?

As I mentioned earlier, efficiency is a critical driver in the Lidar mapping market, and this new technology strives to collect large swaths of data from high altitudes. While Geiger-mode Lidar seems attractive, it has some practical, real-life limitations – such as cloud cover – that often prevent high-altitude operation. As a result, it falls well short of its maximum efficiency in many regions where it must fly much lower. Moreover, it is inherently noisy (low signal-to-noise ratio [SNR]) and relies on extensive smoothing to achieve the high accuracy expected in mapping applications. Complex targets like vegetation are particularly challenging. Finally, its high price point and complex data processing are also limiting factors. In contrast, high-SNR sensors such as the Galaxy have many more collection opportunities throughout the year in areas where clear skies are rare. They are simpler to deploy and operate, and are rapidly closing the gap in collection efficiency while delivering inherently and increasingly more accurate single-shot data. We expect Geiger-mode Lidar to do well in some regions and applications, but believe it will not replace high-SNR sensors.

A combined oblique imaging and Lidar sensor seems to be the latest trend. Is Teledyne Optech offering similar solutions?

Indeed, most sensor deliveries include an integrated camera – RGB, infrared (IR), thermal – and frequently more than one. These cameras are mounted in a variety of ways depending on application requirements. Our standard Lidar/camera mounting systems are very flexible and scalable so clients can fit multiple cameras in various orientations alongside their Lidar systems. Our available mounting options include gyro-stabilised and fixed-mount solutions for aircraft or helicopter pods. We also offer an oblique imaging solution on a carbon fibre frame for urban mapping initiatives.

What other developments do you foresee in the near future?

Sensor technology is clearly evolving in many directions. There is a strong push to develop very compact, low-cost Lidar sensors for unmanned aerial vehicles (UAVs) and even more so for cars. There is also a trend towards ever-higher point density as we strive to achieve blanket coverage of the world around us. Finally, there is the age-old drive for greater efficiency in data collection and processing. The latter is a very important factor in terms of development. Certain industry assumptions, such as the need for a highly skilled sensor operator, are being challenged by autonomous sensors such as the Eclipse and Polaris. These sensors can be programmed to execute survey plans generated at the office without human control. Similarly, data processing is becoming very streamlined, and rapid advances in artificial intelligence (AI) enable increasing automation of high-quality data processing, even in challenging conditions. Finally, the integration of multiple sensor types and high-performance data fusion algorithms, often in real time, is also opening up new applications and opportunities.

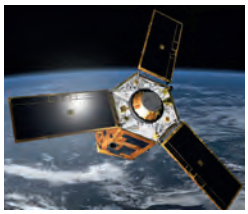
USGS Receives New GNSS Reference Receivers for Volcano Monitoring

PolaRx5.

Septentrio has completed the delivery of PolaRx5 multi-constellation GNSS reference receivers and antenna systems to the U.S. Geological Survey (USGS). The monitoring systems will be deployed through the Volcano Hazards Program (VHP) for volcano monitoring stations in Alaska and at various international locations through the Volcano Disaster Assistance Program (VDAP), a cooperative effort between the USGS and the U.S. Agency for International Development's Office of U.S. Foreign Disaster Assistance. The PolaRx5 receivers take full advantage of the new 5.1.0 firmware which includes support for on-board PPP and dynamic response tuned for seismic applications. The PolaRx5 tracks all visible signals from Galileo, GPS, GLONASS, BeiDou, IRNSS and QZSS constellations. It provides industry-leading measurement quality and robust interference mitigation thanks to Septentrio's patented AIM+ technology.

▸ **http://bit.ly/2ia4jpU**

Celebrating Five-year Anniversary of the First Pléiades Satellite Launch



Pléiades satellite.

Five years ago, the very-high-resolution satellite Pléiades 1A was launched from the Guiana Space Centre, joined by its twin Pléiades 1B a few months later. That marked the start of what is known as the Pléiades constellation, which makes it possible to create imagery of every point of the globe at a 50cm resolution within a few hours and to guarantee a daily revisit, with more than one million square kilometres' worth of data acquired each day. The Pléiades constellation demonstrated its reactivity during the earthquake that rocked Ecuador on 16 April 2016, providing imagery of the town of Pedernales just four hours after being acquired. Immediately delivered to the local authorities, this enabled organisers to coordinate the various relief operations and to carry out a rapid assessment of the damage.

▸ **http://bit.ly/2ia8ZvR**

INTERVIEW WITH AIDAN MERCER, BENTLEY SYSTEMS

Capturing, Modelling and **Building the Reality**

Bentley Systems held its annual Year in Infrastructure Conference in London, UK, from 1 to 3 November 2016, which featured industry executives discussing the latest innovations in technology for architects, engineers, constructors and owner-operators. Bentley is a leading provider of software solutions for advancing infrastructure. The event was an excellent setting for a meeting with Aidan Mercer, global industry marketing director for utilities and government. In the in-depth discussion, he talked about the role the company plays in advancing the world's infrastructure and how geomatics is a key element of many of Bentley's applications.

We're hearing a lot about reality modelling at Bentley's Year in Infrastructure Conference. How can governments and local authorities benefit from the rapid developments in reality modelling?

This year we have indeed talked a lot about reality modelling, and we are excited to announce it is 'going mainstream', as our CEO Greg Bentley has said. What does he mean by that? In 2015, we talked about a Bentley application called ContextCapture, which takes digital photographs and automatically turns them into a photorealistic 3D model of existing site conditions. This year we're focusing on the consumption of that captured data; how infrastructure professionals can utilise the 3D models that are captured through digital photographs for operations, maintenance and various purposes. One of the most exciting announcements we've made at the conference related to ContextCapture is a new feature for 'hybrid inputs' – to combine point cloud data and digital photogrammetric data into a single model, or reality mesh. This means our users can use both sets of technologies, enhanced by ContextCapture. Previously, there was a debate about which technology to use. Now, that's no longer debatable because the technologies are complementary. For government entities, this means that by using this technology they can be innovative in terms of capturing existing assets, large or small. Of course, inside a city there may be different types of infrastructure assets and with a lot of different stakeholders – ranging from the urban planning department to water utilities, energy utilities and building regulators – that want very specific information. Therefore, the ability to capture the existing site conditions with hybrid inputs can significantly benefit stakeholders that might want to access these models. A prime example of a government using this technology innovatively is the City of Helsinki, a long-standing user of Bentley 3D modelling technology. In fact, they won a 'Be Inspired' award in the Innovation in Reality Modelling category at this year's Year in Infrastructure Conference. That project, entitled 3D+, will publish a huge amount of data and make it usable and accessible for the public. They took more than 50,000 images and created a highly accurate, stunningly visual model of the entire city. This illustrates the value of capturing data and saying "This is beneficial for the citizens of our city". It's incredibly innovative and I think, in many cases, governments are at the forefront of innovation – they just don't quite get the credit they deserve.

Combining unmanned aerial vehicles (UAVs) and laser scanning (Lidar) has been discussed at the conference several times. Is this the new magic formula for capturing reality?

That's an interesting question. What we are seeing from these different capturing devices is the potential for them to be complementary, offering a new formula for the end users. Technology companies like Topcon have specialised in this for many years and offer some of the best solutions in the market. I can only talk from a software perspective, but we see the huge value in these technologies. Coincidentally, we issued a press release during the conference announcing a joint partnership with Topcon, resulting in the tight integration between Bentley's ProjectWise and Topcon's MAGNET Enterprise application. This partnership demonstrates a great level of commitment to integrate by software and hardware vendors. It means that the data captured using UAVs or laser scanning devices can be used in engineering workflows enhanced by software and managed with engineering precision. At Bentley, we fully believe this partnership offers real potential to enhance our offering, and I know Topcon is equally excited to leverage our technology for better reality capture. Certainly, enhancing or enabling technologies such as UAVs will help create those 3D models for better precision and better accuracy.

Sometimes it seems like everyone nowadays can capture the environment, for example using cameras, UAVs and maybe even smartphones. But then comes the processing. Which 3D modelling solutions does Bentley offer?

ContextCapture is an automated engine that creates a realistic 3D mesh from the digital photographs and point clouds. There is also ContextCapture Center, which is the large-enterprise opportunity to process huge

amounts of data for some of the bigger projects. It helped with processing power in the Helsinki 3D+ project, for example. Processing power can potentially have huge limitations; we have announced a lot of advancements in our software through the CONNECT Edition, our next generation of software, which is enabled by Microsoft Azure's cloud platform. This means more computational power to deal with intractable files like point clouds, for example. Reality meshes are a lot more scalable, more lightweight and the hybrid modelling feature ensures reality models are easier to manage – further enabling that mainstream approach to reality modelling. Other reality modelling software we offer includes Bentley LumenRT, an application that helps to enliven designs. This adds what we might recognise as a gaming environment to infrastructure workflows. For example, it can visualise different types of environments for the captured reality, enlivening it with shadows, sunlight and vegetation to name but a few. Another very significant advancement this year has been the announcement of the availability of OpenRoads Designer. This comprehensive application goes from conceptual design through detailed design, right through to construction of a project. This is a collaborative 3D environment that enlivens designs but also includes the engineering data associated such as providing cost analysis instantaneously, offering varying options for the most optimal designs. We're seeing so many advancements with 3D, but it's important to note that geocoordination with the assets created is intrinsically built into our technology. In other words, we see the pervasive value of geospatial data being omnipresent as we develop our own platforms or ensure interoperability with other providers to ensure the 3D data created and consumed has a geo context.

One of your solutions concerns land management and cadastral mapping topics that depend on local culture and laws. How do your solutions adapt to the regional differences?

Given the variances in land management and cadastral mapping requirements, it does require a unique approach to providing software that can adapt to regional and local cultures and laws. Bentley Map, for example, provides users with a platform for mapping, analysing and publishing land or cadastral data. We've seen a broad level of adoption for such technology but, in most cases, users require the solution to be adaptable and robust. The platform itself is highly interoperable with other solutions such as Oracle Spatial, Esri ArcGIS or CityGML to ensure standards and specifications are met. Bentley is a platinum member of Open Geospatial Consortium (OGC), so we are committed to ensuring the software we provide is open. It's true that we see a very wide-ranging use based on the requirements of each region, and levels of mapping maturity vary. Some organisations are still using paper-based drawings for certain areas of their region, while others are already fully digital. We see focus areas and adoption in countries like the Czech Republic, The Netherlands, Mexico, Ireland, Finland, Singapore, the USA and Canada, to name but a few. The platform can be used as a stand-alone application or added to MicroStation – Bentley's flagship modelling application – to be installed on a desktop to provide web-publishing opportunities, which allows data to be published through a portal.

So there's a lot of use cases that enable it to be utilised by various land administration agencies.

Open source seems to be the new paradigm for many software developers all around the world. How does open source affect your business on proprietary solutions?

There has been a huge amount of work done on open source data. With OGC, for example, we are very much involved in discussions based around open standards, open data and the benefits – and of course also the risks – associated. Being involved in that discussion helps us to ensure our software meets those needs and requirements. There is also a lot of discussion around cyber-security and data governance, especially as we move to the cloud. People have their concerns about what that means for the data itself, and rightly so. But, at Bentley, data security is taken extremely seriously, and that's why we collaborate with Microsoft and the Azure platform, which provides our users with fast, reliable and safe environments for their data. We know that it's essential for many users, and our applications enable a connected data environment, which is what we call 'open and live': it's open, but not for everyone – it's open for interoperability with other solutions. But it's got to be open now; this is the new way of working and that's intrinsic in all our applications. We see publishing data and open standards as the way forward, especially for government accounts, for people consuming, accessing and making decisions based on that data. We're big proponents of making sure that our solutions enable open-data formats and standards.

Building information modelling (BIM) is a hot topic, and the role of BIM will continue to grow. The construction industry sometimes seems to be reluctant to incorporate BIM into the bigger picture of 3D geoinformation, often leaving BIM as unconnected, isolated islands of information. How is Bentley contributing to the integration of BIM and GIS?

Let me first explain how Bentley defines BIM. We see BIM as a coordinated set of processes supported by technology, so it's not necessarily just about the model in isolation. If we agree that BIM is a process, BIM is less about the isolated model itself – the models created by engineers add far-reaching value and could be described as digital engineering models. The entire asset lifecycle to facilitate the process of BIM has been a major focus for Bentley for many years, grasping the importance of connected data environments to ensure a collaborative BIM. It is also vital to connect BIM data to other sources of data. Bentley's AssetWise CONNECT Edition platform ensures the potential of BIM is realised as it connects different sources of data, such as IT, operational technology (OT) and engineering data. The data created by engineers in early phases enables digital engineering models to carry asset information through all phases of the lifecycle. If all this data can be converged in a connected data environment, then this open and live platform can be a mechanism for exchange of rich asset data at different stages of the infrastructure lifecycle. The UK is a leading force in standardising BIM processes as the government recently mandated BIM Level 2 on government-funded projects to ensure collaboration and consistency. One telling sign is that this BIM process has already yielded positive results. It does mean a disruptive change for architecture and engineering design firms that need to adhere to certain standards to participate in those government projects, but their value is being collectively recognised throughout the entire project. The construction industry is becoming more aligned to a better format and it will essentially benefit projects, leading the industry to become more tech-savvy and a better adopter of technology. Thus, we will see better cost savings and, in a time of reduced budgets, it can drive more value for owners. Of course, we must not forget the value of having geocoordination in these models that are full of rich asset data that includes spatial information. There is a lot of noise in the industry about integration between GIS and BIM, and I expect this to continue in the years ahead as a mutually beneficial process.

In 2015 Bentley acquired Acute3D. How does this acquisition complement Bentley's business?

Acute3D is now known as ContextCapture, which gives us the ability to reach new audiences, and it also offers us the opportunity within our current user base to expand their skills and understanding of how to capture real-world conditions with the far-reaching potential of a reality model. It has made engineering very interesting, very relevant, very visual and more affordable. I can imagine that every maintenance crew will soon be armed with a UAV and a software licence that allows them to continuously survey their assets, for ongoing construction, for whatever purpose they may have.

Many technology companies in the US and EU are facing increasing competition from Asian countries. How do you cope with global competition in terms of dedicated solutions, regional support to customers and price-setting?

The way we look at it is that competition helps drive your business. The innovations that we've seen at our Year in Infrastructure Conference are reflective of a company that is making huge advancements in software, and our users are incredibly excited. I think that's also reflected in the mood at this year's conference; we've completely sold out, we've got to look for bigger venues in the future, so if you look at it from the point of view of our users and the feedback that we get, then the competition will look after itself, I suppose.

What have been some of the key highlights of the 2016 Year in Infrastructure Conference?

The highlight for me, every year, is our 'Be Inspired' awards, which recognise the best infrastructure projects around the world. We've had more submissions then we could ever anticipate, and the quality of the projects gets better every year. It gives us a good opportunity to reflect on how our software is used around the world to advance infrastructure but also to sustain it. It gives us that nice feeling as a company that, from a software perspective, we're making a difference. Let me give some inspiring examples from the Innovation in Reality Modelling category alone. I've already mentioned the Helsinki 3D+ project, but another project that is worthy of a mention is the Los Angeles College District's BuildLACCD that's helping to improve campuses by delivering new buildings and remodelling existing ones. The new educational facilities aim to retrain some of the students in software usage, offering a BIM track of study that looks at how digital engineering models can be used extensively. I would say the Los Angeles College District, which won the award for Innovation in Government, is a pioneer of a BIM approach in the US, fully understanding the connected data environment, and was a worthy winner. The Los Angeles College District has over 500 different project participants are all utilising the same digital engineering models and it has yielded some significant returns on its investment outlay. Some great projects have been presented here, reflecting the wide range of possibilities our solutions offer, and we're already looking forward to next year's edition in Singapore! ◂

AIDAN MERCER

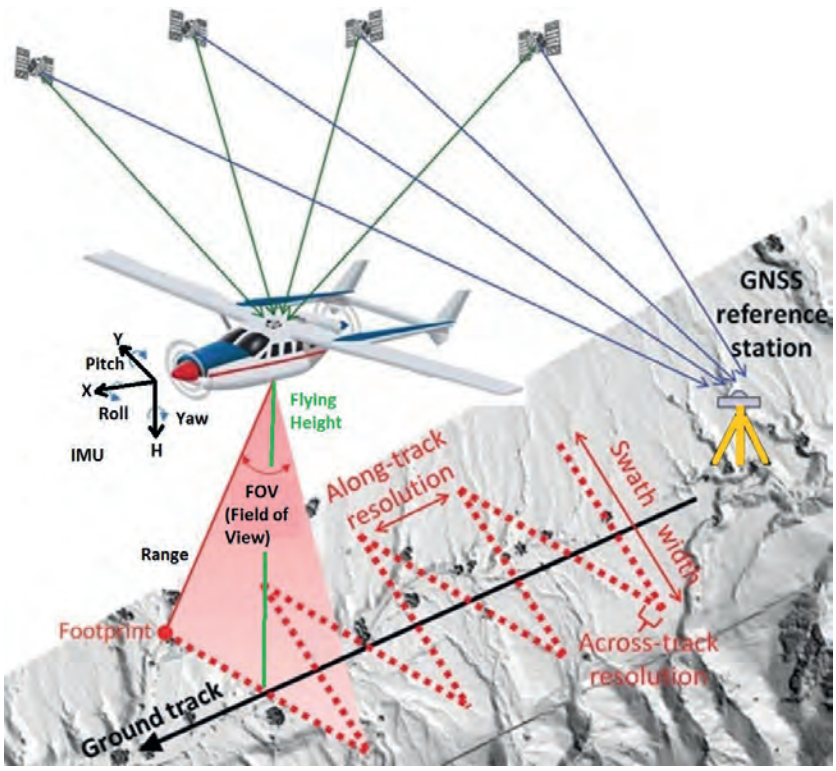
Aidan Mercer is industry marketing director at Bentley Systems for water and wastewater, electric and gas, communications and government. He has held various roles in geospatial and utilities marketing within Bentley and previously held various marketing roles in similar high-tech organisations. Mr Mercer fills a variety of roles on technical committees and industry bodies related to geospatial and smart cities.

A VIEW ON STATUS, DEVELOPMENTS AND TRENDS

The **Fierce Rise** of Airborne Lidar

Today, automatic matching of overlapping aerial imagery and airborne Lidar are the main geodata technologies for capturing dense point clouds of the Earth's surface. The sampled points are used for the generation of bare ground representations which are often augmented with buildings and trees. Airborne Lidar is flourishing as a prevalent geodata acquisition technology and continues to show a fierce rise in terms of advancements and applications. This article discusses the main technological advances of today's operational systems and surveys the state of the art, developments and trends.

Having trained as a geodesist and photogrammetrist, I first started conducting research into laser scanning and more specifically airborne Lidar in early 1997. Ever since I have regularly reported on and discussed the state of the art and developments – often in the form of product surveys – in the pages of *GIM International*. Over the past 20 years, airborne Lidar has made admirable progress and has gone mainstream, joining aerial photogrammetry as an important geodata acquisition technology for creating digital elevation models (DEMs), digital surface models (DSMs), orthophotos and derived products, 3D models of cities and 3D digital landscape models. Indeed, airborne Lidar has evolved into a most successful geodata acquisition technology used for multiple applications, including forest stand monitoring, urban planning and monitoring, natural resource management, disaster management, corridor mapping, hydrological modelling and forest carbon monitoring.



▲ *Figure 1, GNSS and IMU enable automatic calculation of the X,Y,H coordinates of ground points from range and scan angle; across-track scanning is performed using a nutating mirror.*

FROM RETURNS TO POINTS

Over the course of time, design and engineering of airborne Lidar systems have mainly been concentrated on improving the resolution, i.e. point density, and the amount of attributes recorded per individual ground point. Initially the main end product was considered a DEM or DSM. Therefore, the emphasis was on calculating X,Y and H coordinates of the individual points in a preferred local or regional geodetic reference system using GNSS and an inertial measurement unit (IMU). Figure 1 sketches the basics of the computation of X,Y,H coordinates of Lidar points. An additional attribute recorded was the strength of the return. In many applications this strength was used for checking and quality assurance purposes only and was discarded once the DSM or DEM had been created and approved. Filtering, i.e. the removal of unwanted points such as multipath outliers, points on cars, cows or other cattle, was done by checking whether a point fitted within a neighbourhood of points using geometric

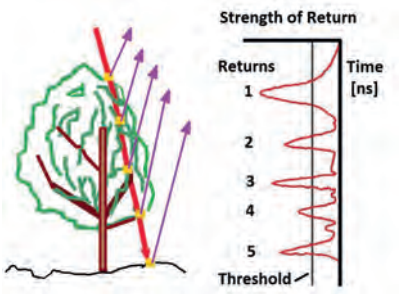


Figure 2, Digitisation of multiple returns in a forest area: first, last and three returns in between (Courtesy: M. Lemmens).

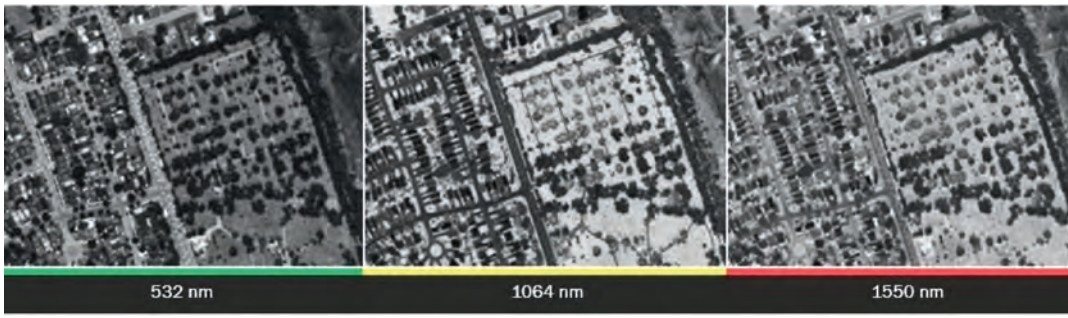


Figure 3, Multispectral images created from a Titan airborne Lidar system manufactured by Teledyne Optech.

constraints. When the aim was to create a DEM, i.e. a bare ground representation, points which reflected on buildings and vegetation had also to be removed. A lot of academic research has been devoted to the automatic detection of unwanted points.

FULL WAVEFORM DIGITISATION

The more attributes that are recorded per point, the better the assignment of classes will perform. The desire to collect more and more attributes resulted in two major advances. The first of these occurring on the market was full waveform digitisation (FWD), in which not only the first and last return are recorded but rather the entire return is sampled in regular intervals. This capacity to sample the entire return has now been available from all major manufacturers for nearly a decade.

Initially, most airborne Lidar systems detected the first return reflected from objects on the Earth's surface hit by the laser pulse. In forestry, which was an important application area in the early days, foresters discovered that it would be beneficial if not only the reflection on the canopy (first return) but also the ground underneath the trees could be captured to generate a bare ground elevation model (DEM). In response, manufacturers introduced facilities to capture the last return in addition to the first return. The approach was based on the observation that the foliage cover is usually not completely impermeable but rather semi-porous; a part of the pulse may reflect on leaves but gaps between the leaves allow the pulse to reach the ground and to be scattered back to the Lidar receiver. In other words, the first return reflects off the foliage and the last return off the ground, i.e. indicating the bare ground and thus suited for DEM generation. The difference between the last and first returns provides a measure of the height of the tree and ultimately the forest stand as a whole.

The recording of the backscatter of each emitted pulse did not stay limited to two returns for long. To allow more information to be derived from the data, returns also started to be recorded between the first and last return (see Figure 2) finally resulting in full waveform digitisation. FWD samples the entire return signal from its leading edge to its trailing edge at regular intervals, e.g. 1ns.

INCREASED POINT DENSITY CAN BE ACHIEVED BY COMBINING SEVERAL LIDAR HEADS INTO ONE SYSTEM

Depending on the sample interval and the height of the object, either 64, 128 or 256 samples are taken. FWD requires huge data storage capacities, of course, but benefits from the fact that it generates more attribute data about ground features, resulting in more reliable classification of objects and a refined classification scheme.

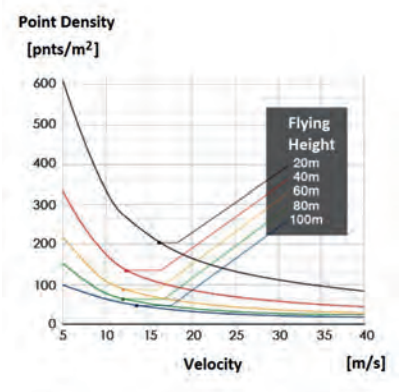


Figure 4, Relationship between point density, aircraft speed and flying height of the Phoenix Alpha AL3-32 Lidar system, weighing 3.2kg.

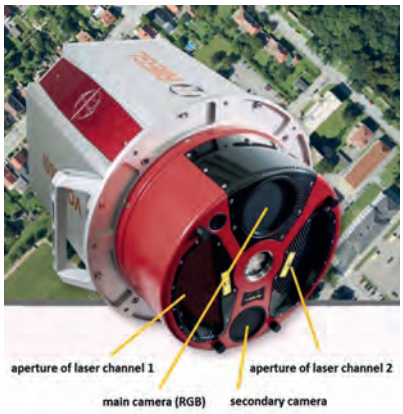


Figure 5, RIEGL VQ-1560i, consisting of two laser scanners and two cameras.

MULTISPECTRAL LIDAR

Multispectral Lidar can also increase the number of attributes per ground point. In December 2014 Teledyne Optech introduced the world's first multispectral airborne Lidar, called Titan. Three independent pulses – wavelengths 532nm, 1,064nm and 1,550nm – are emitted, each with a 300kHz effective sampling rate for a combined ground sampling rate of 900kHz. When the point density is high the system produces, after gridding, an image-like picture (Figure 3). Uses include topographic surveying, 3D land cover classification, environmental modelling, vegetation mapping and shallow water bathymetry.

▲ *Figure 6, The RIEGL VUX-1 Lidar system is small enough to be carried by a UAS.*

MULTIPLE PULSES IN AIR

Point density depends on a number of system parameters including pulse frequency, rotating speed of the scanning mirror, field of view, the speed of the aircraft and the flying height. Figure 4 shows the relationship between point density, flying height and aircraft speed for a particular Lidar system. One of the limitations of the early Lidar systems to increase point density was that the return of the previous pulse had to be captured by the sensor before the next pulse could be emitted. This was necessary to avoid confusion between returns of subsequent pulses. At a flying height of 1km and given that the speed of light is approximately 300,000km/sec, the pulse frequency, also called laser pulse repetition rate, could thus not exceed 150kHz. However, using smart solutions embedded in the system, the phenomenon of multiple pulses in air was introduced, largely eliminating the limitation discussed above.

In March 2014 Swedish firm Airborne Hydrography AB (AHAB), which has been part of Leica Geosystems since October 2013, launched the Dual Head consisting of two scanners each emitting up to 500,000 pulses per second, totalling a pulse frequency of 1MHz. When flying at a height of 1km, the point density is 16 points per square metre. Leica has not only combined two oblique laser sensors into one system to increase pulse frequency, but has also added two digital cameras: one for high-resolution imagery and one for quality control. The system has been specifically designed for surveying urban environments with many high-rise buildings and other objects that complicate 3D mapping as well as utility corridors with obscured objects.

LIGHTWEIGHT, COMPACT AND LOW-ENERGY LIDAR DEVICES HAVE RECENTLY BECOME COMMERCIALLY AVAILABLE

In order to increase point density, RIEGL introduced a dual-channel system which was released at Intergeo 2016: the VQ-1560i (Figure 5). This waveform processing system has a pulse frequency of up to 2MHz, resulting in 1.3 million measurements per second on the ground. The operation altitude is up to 5km, making the system suitable for multiple tasks including ultra-wide area mapping, mapping of complex urban environments, city modelling, corridor mapping, agriculture and forestry.

COMPACT

Unmanned airborne systems (UASs) have garnered the earnest interest of a broad group of geomatics professionals. UASs have proven to be a reliable technology for capturing 3D geodata of small areas, individual buildings or complexes of man-made structures using cameras. Up until recently the use of airborne Lidar was largely confined to manned flights, mainly due to the fact that Lidar sensors used to be heavy – in the order of tens of kilograms – and consume a lot of power which constrains

▲ *Figure 7, The YellowScan Mapper lightweight Lidar system in operation.*

their use on small, unmanned aircraft. As a result, until recently UAS Lidar surveys were unfeasible for all but the very largest UASs. Overcoming this barrier requires small dimensions as well as low weights and modest power consumption. I consider a few of them below, ranked according to weight.

LIGHTWEIGHT SYSTEMS

RIEGL's VUX-1, introduced in 2016, weighs around 3.5kg and is compact enough to be mounted on a variety of small fixed-wing and rotary unmanned aircraft (Figure 6). The system captures up to 200 parallel scan lines per second while up to 500,000 measurements per second can be recorded. The manufacturer claims an accuracy of 10mm. The flying height is over 300m and the field of view is up to 330°. Next in line is the Alpha AL3-32, manufactured by Phoenix Lidar Systems based in Los Angeles, California, USA. This Lidar device weighs 3.2kg, the maximum flying height is 100m, the pulse frequency is 700kHz, the field of view is 360° and two returns per pulse can be recorded. Smaller than the AL3-32 is the Alpha AL3-16. This system fits in a box measuring less than 25cm square and weighs 2.2 kg. The maximum flying height is 100m, the pulse frequency is 300kHz, the field of view is 360° and two returns per pulse can be recorded. For both the AL3-32 and the Alpha AL3-16 the manufacturer claims an absolute accuracy of 25/35mm at a flying height of 50m. As the systems operate fully autonomously, they can be mounted not only on a UAS but also on cars, boats or backpacks. At 2.1kg the YellowScan Mapper, introduced in 2014, weighs a little bit less than the Alpha AL3-16 (Figure 7). The maximum flying height of the Mapper is 100m, the pulse frequency is 40kHz, the field of view is up to 100° and three returns per pulse can be recorded. According to the manufacturer, its main applications are archaeology, construction, forestry and corridor mapping. In 2016 YellowScan, based in France, introduced a system called the Surveyor with an even lower weight: just 1.5kg. The maximum flying height is 50m, the pulse frequency is 300kHz, the field of view is up to 360° and a maximum of two returns per pulse can be recorded. The applications are focused on mining, civil engineering and corridor mapping. When it comes to lightweight systems, to date the Velodyne Puck appears to be the champion – it fits into the palm of a human hand and weighs 830 grams (Figure 8). The maximum flying height is 100m, the pulse frequency is 300kHz and the field of view is 360°.

THE MAXIMUM DISTANCE A LIDAR PULSE CAN BRIDGE DEPENDS ON POWER, PULSE FREQUENCY AND REFLECTIVITY

The maximum distance a Lidar pulse can bridge from sensor to ground and back depends on the power used, the pulse frequency and the reflectivity of the part of the object hit by the pulse. For example, when the reflectivity is 20% assuming flat terrain and the pulse frequency is 50kHz, the maximum operational flying height of RIEGL's VUX-1 is 350m. This figure reduces to 55m when the pulse frequency is increased to 550kHz and the pulses are emitted with reduced power.

EASE OF OPERATION

The design of an airborne Lidar system depends not only on the needs of a specialised group of geomatics professionals who are used to capturing (ultra-)wide areas. Other professionals with modestly sized projects appreciate simplicity and ease of operation. For these types of users Teledyne Optech introduced the Eclipse in 2016 (Figure 9). This airborne Lidar system weighs 36.6kg and focuses on data collection of small areas using low-cost platforms. The system operates largely autonomously; one pilot is needed on board for navigation but no operator.

▲ *Figure 8, A demonstration of the miniaturisation of Lidar sensors; shown is the Velodyne Lidar Puck VLP-16.*

CONCLUDING REMARKS

Today, data collected from sensors mounted on aircraft can compete with data captured on the ground in terms of efficiency, accuracy and level of detail. Just 20 years ago surveyors would have expressed disbelief at the thought of such a silly idea. Lidar technology is still making strong progress which makes me curious about what the next couple of years will bring us. One interesting development is single photon Lidar (SPL). The few systems in operation to date enable a hundredfold increase in the point density. The principle is based on splitting a single emitted pulse into tens to hundreds of sub-pulses. One pulse thus results in an array of returns which enables an increase in the point measurement rate to 100 million points per second or more. ◀

▲ *Figure 9, The Eclipse has been developed for use by project engineers who prefer ease of operation.*

MATHIAS LEMMENS

Mathias Lemmens gained a PhD degree from Delft University of Technology, The Netherlands. He acts as an international consultant and is the author of the book *Geo-information – Technologies, Applications and the Environment* published by Springer in 2011. He is currently working on a book on point clouds.
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BY **FRÉDÉRIQUE COUMANS**, CONTRIBUTING EDITOR

WINNER OF PAN-AMERICAN THESIS CONTEST

Protecting **Location Privacy** Brings Opportunities to the Geosector

Since members of the geosector are well versed in potential applications of geoinformation and its fusion with other data sources, they are best equipped to devise and test technology-based solutions for location privacy-related challenges. That is the opinion of Dara Seidl, a young expert on geoprivacy, who won the first pan-American master's thesis contest on geoinformation.

▲ *Dara Seidl, doctoral candidate/teaching associate at the San Diego State University: "Privacy considerations should not be seen as restrictive to the growth of the geomatics sector. Instead, the incorporation of privacy-preserving techniques can be a new area of growth."*

Dara Seidl was selected by a jury of worldwide experts as the winner of the 'Prize for the Outstanding Master's Thesis in Cartography, Geodesy and Geo-Information 2015' for her thesis titled 'Striking the Balance: Privacy and Spatial Pattern Preservation in Masked GPS Data'. The prize is awarded each year by the Pan-American Institute of Geography and History (PAIGH, based in Mexico). Seidl wants to help to protect location privacy: the right of individuals to determine how, and the extent to which, their location information is shared with other parties.

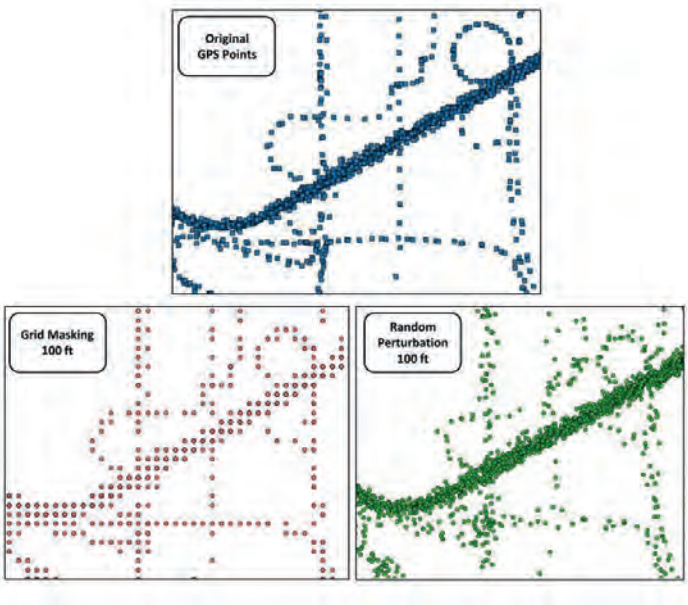
Geoprivacy is a hot topic in the face of increasing digital surveillance by governments and as private companies are increasingly exploring the benefits of location-based services. Both private and public organisations encourage people to volunteer as much data as possible in their cars or via their phone to help the organisations to 'improve their service'. Even if they have nothing to hide, many people may prefer to decide for themselves which information they share.

The big data industry sees location as a crucial component to enable its analytical programs to extract meaningful results from the huge heap of data puzzle pieces. The flip side is that location is a strong personal identifier, primarily because of its role of linking disparate sources of data. More and more people are perceiving a risk in the growing capability to combine volunteered and non-volunteered data from various sources into personal profiles. Such profiles, which may be inaccurate, can subsequently be shared without consent, misused by authorities, insurance companies, etc., or even hacked.

The public release of government data with a location component in the interest of open data has a number of important advantages but, even in the case of public records, privacy issues merit attention. For example, in 2013, a newspaper in New York State caused outrage when it released an online map of gun owners from requests listed in public records. Related applications include remote sensing for change detection in the built environment, or mobile mapping images of every dwelling. And most individuals leave digital footprints that are picked up in big data, such as through their social media posts, credit card transactions and travel-card usage.

DIGITAL FINGERPRINT

GPS data from cars, smartphones or other devices create unique personal patterns. A 2013 study by de Montjoye et al (http://www.nature.com/articles/srep01376),



▲ *Example of GPS obfuscation results with a 100-foot distance threshold.*

based on an anonymised dataset of mobile phone interactions for 1.5 million people, concluded that the use of just four location points over 15 hours is sufficient to identify 95% of all individuals. In the study, the authors examined the number of location points shared between traces within one hour to determine how many spatiotemporal points are necessary to make the trajectory unique. Consider a GPS dataset that contains waypoints for an individual's daily commute. Even if the GPS dataset contains no other information about the person other than a unique anonymous identifier, specialists can still likely determine that person's home address, place of work and other frequently visited locations, which can in turn be linked to other openly available data. Then, in the auxiliary data, the specialists may discern more sensitive information about the individual, including name, gender, age, marital status, health information, occupation and hobbies. In the health realm, location is termed a 'quasi-identifier' for its ability to establish links between background information and a given dataset. The identifying power of GPS data goes further than database linkage in that a sequence of locations provides clues about individual characteristics, such as whether the person is a parent indicated by visits to a school in the morning and afternoon with other locations in between.

Location remains a personal identifier even if the data is aggregated in a central server and becomes part of 'big data'. If geodata about individuals is not properly encrypted, centralisation in a server creates a high potential privacy risk since it may be linked with other personal attributes. Seidl points out: "Even though a given individual may seem anonymous in a flood of big data, his or her personal location data is unique enough to be identifying, like a digital fingerprint. As we improve and develop new technologies that collect increasingly fine-grained and high-volume geodata, we should not disregard ethical considerations."

PRIVACY: THE RIGHT OF INDIVIDUALS TO DETERMINE HOW, AND THE EXTENT TO WHICH, THEIR LOCATION INFORMATION IS SHARED WITH OTHER PARTIES

OBFUSCATION

The anonymisation techniques Dara Seidl applied in her thesis are not computationally expensive, even for large volumes of data. The datasets she used contained close to one million points, and the masking procedures themselves took very little time to run. More complex procedures may require a longer processing time to evaluate levels of privacy and spatial distribution. For example, some anonymisation techniques are coded as optimisation problems, maximising the preservation of spatial pattern while maintaining some threshold privacy value. In Seidl's view, these conceptualisations tend to require more time to complete, but should not be cost-prohibitive. And, of course, the decision to use obfuscation techniques should always be dependent on the particular considerations of the dataset and the estimated privacy risks.

How does obfuscation work? Obfuscation, also known as 'masking', introduces slight inaccuracy to geographic data with the goal of protecting privacy. Each point in a point set is displaced, typically within some distance threshold, so that the associated individual cannot be re-identified based on location, but the spatial pattern of the dataset is preserved at all times. A number of methods exist to achieve this balance, some of which weight the distance of displacement by some characteristic of the underlying population, such as population density. In Seidl's winning thesis, the techniques applied are random perturbation, which displaces each point by a random distance in a random direction within a distance threshold, and grid masking, which snaps each point to the centroid of grid cells of a specified size overlaid with the data.

NEW GROWTH AREAS

Privacy considerations should not be seen as restrictive to the growth of the geomatics sector. Instead, the incorporation of privacy-preserving techniques can be a new area of growth. Dara Seidl: "Those in geomatics are best equipped to understand how personal identities can be compromised in geodata. One argument posed by those who study location privacy is that it is better that those in the geosector focus now on developing effective technical privacy solutions before more stringent or over-protective rules on data collection are imposed through government regulations. I believe that governments and the geosector must work together to familiarise each other with how privacy protection strategies may work in tandem to prevent identity disclosure without stifling the benefits of new technology developments."

Remote sensing and mobile mapping images represent vast and precise sources of geodata that can produce virtual copies of the world.

These industries have already incorporated some important privacy protections, such as by blurring faces and licence plates or omitting data around government or military sites. However, privacy strategies should ideally be in place at the data collection stage. Data collection necessitates storage and, if encryption is inadequate, repositories of data may be vulnerable to disclosure – potentially through hacking activity – before the data even reaches the analysis stage. "Location privacy is not just relevant to clients of collected data, but to anyone who plays a role in data collection," is Seidl's strong opinion.

Geo-ICT companies are looking for new markets and they could certainly offer obfuscation techniques as a selling point. The realms of healthcare, location-based services, banking and transportation have no doubt experienced tensions between data utilisation and privacy concerns, and may even have faced legal action with regard to privacy. It is commonplace in the United States for the geosector to offer privacy protection strategies in project proposals. The most common privacy solutions for geodata are to aggregate or omit data in sparsely populated regions, to establish data enclaves or secure remote access, or to use software agents to perform calculations and provide answers. These solutions are strongly privacy-protective, but remain somewhat at odds with data democratisation and the open access movement, as the public must typically apply for access. Dara Seidl is certain: "This is where obfuscation could become a selling point, by allowing the release of masked geodata without administrative barriers. We are seeing increasing interest in obfuscation techniques particularly in health and transportation research, as well as in citizen science projects."

PAN-AMERICAN CARTOGRAPHY, GEODESY AND GISCIENCE THESIS CONTEST

An annual prize is awarded by the distinguished Pan-American Institute of Geography and History (PAIGH) for the best master's thesis in the specific fields of cartography, geodesy and geographic information science in general, including aspects such as data capture, manipulation, presentation and dissemination. Besides the thesis covered in this article, two further distinctions were awarded in 2015: to Ms Sol Pérez form Mexico (thesis titled 'Atlas de la nueva geografía de la minería en México y los conflictos asociados a ella') and to Mr Bruno Lara from Argentina (thesis titled 'Fragmentaticíon de pastizales en el centro de la provincia de Buenos Aires mediante imágenes landsat'). For 2016, a prize will be awarded at both MSc and PhD level. The goal of the prize is to promote and recognise high-quality academic and scientific work by students on official postgraduate programmes led by organisations or universities located in PAIGH's member states, as well as citizens of such member states who have graduated elsewhere. More information: http://comisiones.ipgh.org/CARTOGRAFIA/Premio_EN.html

MODELLING AN EARLY MEDIAEVAL RING FORT IN GERMANY

Low-cost versus High-end **Systems for Automated 3D Data Acquisition**

Topographic mapping is a standard surveying task and the instrument of choice used to be a total station. The use of terrestrial laser scanning has become popular over the past decade or more, but today there is a much wider choice of methods for the acquisition of a digital surface model (DSM). For the 3D recording of an early mediaeval ring fort, the authors investigated the use of three modern systems: a portable (kinematic) laser scanning system, a static terrestrial laser scanning system (TLS) and a photogrammetric unmanned aerial system (UAS). The systems were compared to each other based on the following criteria: efficiency and performance in the field, degree of automation for data processing, and accuracy achieved in relation to the system costs.

▲ *Figure 1, Aerial view of the ring fort of Lembecksburg, Germany, captured by a Sony Nex-5 camera on a hexacopter.*

THE EARLY MEDIAEVAL RING FORT OF LEMBECKSBURG

The Lembecksburg ring fort is located on the North Sea island of Föhr (Figure 1), 1km north of the village of Borgsum. This circular earthwork was built on top of a geest, or slightly raised landform, next to the Föhrer Marsh. The outer diameter is 140m and the inner diameter is approximately 90m. The height is 10m above the outer ground, while on the inside the ground is only 3 to 4m below the wall top (Figure 1). In earlier times there was a ditch around the outside of the wall. This is difficult to identify today, although it is slightly visible in the east. Until the 19th century there was a tideway from the north of the wall to the Wadden Sea, which was presumably navigable for most of its length. The first construction of the wall dates back to the 8th century – the time of the Vikings – but traces of the Roman Empire (ceramics) have also been found at the archaeological site. Today the complete ring fort as well as the surrounding area is grass-covered.

Data Acquisition Methods and Systems Used

All data was collected by geomatics students from HafenCity University (HCU) in Hamburg,

Figure 2, Scanning while walking using the kinematic laser scanning system from the company p3d systems.

Figure 3, The flight was controlled manually due to the strong gusting wind.

Germany, during a three-day measurement campaign. The reference data was surveyed using a Leica TCRA 1201 total station. A total of 550 topographic points were recorded covering the wall and the centre of the ring fort. For the static TLS data, the Zoller + Fröhlich IMAGER 5010 laser scanner was used. From 42 stations, an amount of about 12 million points per scan was acquired, which corresponds to a total number of approximately 504 million points and a scanning time of about 12 hours. For the registration of the scans at least five black and white targets per scan were used, which were determined by total station in a local coordinate system. The kinematic laser scanning was carried out with the ProScan system, provided and operated by the company p3d systems GmbH from Hamburg. This system is equipped with a TLS – in this case the IMAGER 5010 from HCU – plus a GNSS antenna and a high-precision inertial measurement unit from iMAR Navigation GmbH. Additionally, a GNSS reference station was needed for the system positioning, which was installed in the field close to the ring fort. To carry the 18kg system in object space, the sensor components were mounted on a special carrier known as a steadicam (camera stabiliser mount) used in the film industry (Figure 2). During walking the operator is able to control the system using a tablet PC. In total, four tracks were scanned in two hours by three operators, covering a length of 1,143m and an amount of 154 million points. For UAS photogrammetry a hexacopter Sky Hero Spy 750, equipped with a gimbal-mounted digital camera (Sony NEX-5, 16mm focal length, 14 megapixels), was used. 186 images were taken during an eight-minute flight, which was controlled manually rather than in automatic flight mode due to the strong gusting wind (Figure 3). For georeferencing of the image block, five targets for XYZ control points were distributed around the object and determined by total station.

DATA PROCESSING

The collected data was processed in such a way that similar and comparable datasets were obtained for each sensor. For the georeferencing of the point clouds, however, different processing procedures were implemented. For the p3d systems data the trajectories were calculated in the PCloud software in order to generate one point cloud for each track. The GNSS signal from the reference station was used to transform the data directly into UTM XY coordinates, while the height was adjusted by a constant shift. The positioning accuracy of the tracks was approximately 2 to 3cm. The static laser scans were georeferenced using the scanned targets; each station was registered using the target coordinates from total station measurements with a mean deviation of 2.4mm. The UAS image data was triangulated in Agisoft PhotoScan using five control points in a bundle adjustment for the determination of the image orientation and camera calibration parameters. The residuals of the control points after adjustment were less than one centimetre. The three different point clouds from kinematic TLS, static TLS and UAS photogrammetry were sampled down to 15cm point spacing. For the comparison, the ring fort itself plus an area of 40m around the ring fort was investigated. Each data volume was thus reduced to 1.2 million points. Finally, from each of the three point clouds, two datasets were derived for each sensor system. For the first, the point cloud was meshed in Geomagic with the 15cm point spacing, and for the second dataset a regular grid with 20cm point spacing was derived by filtering, where the lowest point was kept for each cell. In illustration, Figure 4 shows the

Figure 4, The mesh from the UAS data, filtered to a 20cm grid cell using the lowest point.

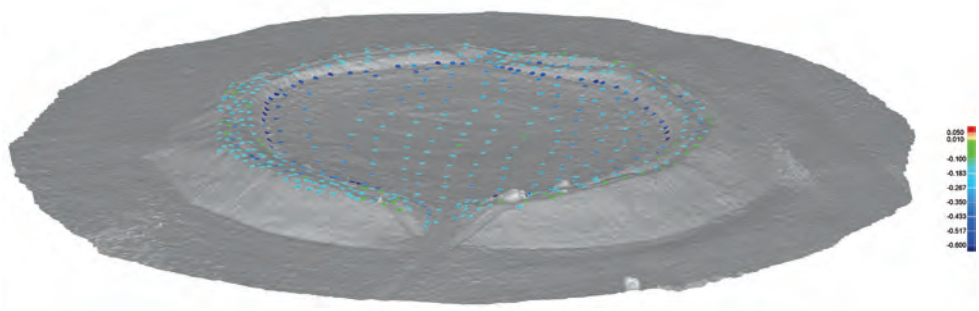


Figure 5, Spatial distribution of the reference points from total station including colour-coded differences with the test system.

System	SC [EUR]	deviations of dataset 1 [m] (15cm point spacing)			deviations of dataset 2 [m] (lowest point in 20cm cell)			time [h]
		ø	MIN.	MAX.	ø	MIN.	MAX.	
TLS	50,000	-0.28	-0.87	0.02	-0.22	-0.87	0.09	25
p3d	150,000	-0.26	-0.79	-0.03	-0.19	-0.90	0.06	5
UAV	5,000	-0.27	-1.21	0.01	-0.25	-0.99	0.03	5
SC = System Costs, Time = Amount of time for data acquisition and processing								

▲ *Table 1, System costs, height differences compared with the reference dataset and amount of time involved in the three different measurement systems.*

mesh from the UAS data, which was filtered to a 20cm grid using only the lowest point.

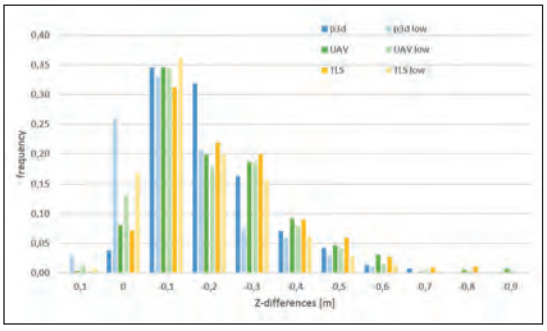
COMPARISON OF DERIVED DATA

To obtain information about the accuracy of the DSM generated, the different models were compared to the reference data of the total station (Figure 5). Due to the long grass on the ground, which was estimated to be up to 40cm in height, significant differences are visible in all DSMs; none of the three tested methods is dominant. Assessing the meshed models without filtering achieved the following results:

The proportion of points having a maximum deviation of 20cm is 39% for the static TLS with IMAGER 5010, 43% for the UAS photogrammetry and 38% for the kinematic TLS from p3d systems. In comparison with the results for the filtered data, the proportion of points with max. 20cm deviation is higher for all methods, but not to a similar degree. The p3d systems dataset has improved significantly to 63%, the IMAGER 5010 dataset is now at 53%, while the UAS dataset shows a slight rise to 49% (Figure 6). Here it is clearly apparent that dense image matching is not able to generate 'real' ground points in the case of low vegetation such as grass or meadows. Nevertheless, the laser scanners have also problems with the grass height; on the one hand they deliver better results close to the scanning stations, but on the other hand points with increasing distance to the scanner station have similar deviations as the UAS data due to the scanner's angle of incidence. Table 1 summarises the deviations in height against the reference dataset, including the amount of time spent on data acquisition and processing in relation to system costs.

CONCLUSIONS

The authors investigated three different systems and methods for DSM generation and compared the achieved datasets against a reference dataset. Due to the long grass and vegetation, the mean deviations in height against the reference dataset were up to 30cm. Additional filtering of the datasets slightly improved the results, but could not eliminate the differences. Overall, the p3d systems dataset was evaluated to be the best one, followed by static laser scanning and UAS photogrammetry. Taking into account the time spent on data acquisition and processing, with a workload of five hours the kinematic TLS and the UAS photogrammetry are much more efficient methods than the static TLS which has a workload of 25 hours. It has to be assumed that in the case of less vegetation the UAS-generated data could obtain a similar quality in comparison to the kinematic TLS. Due to the low system costs, UASs are an alternative solution to static and mobile laser scanning. However, the slightly better results in this investigation were achieved by a high-end system costing approximately EUR 150,000, which might be an exclusion criterion for many applications. ◀



▲ *Figure 6, Frequency distribution of Z differences between reference (total station points) and two different DSM datasets, each derived from three different sensor systems.*

FURTHER READING

Kersten, Th., Lindstaedt, M., Mechelke, K., Omelanowsky, D., Prenting, J., 2016. Low-Cost vs. High-End Systeme im Vergleich – 3D-Aufnahme der Ringwallanlage Lembecksburg auf der Nordseeinsel Föhr (in German). *Photogrammetrie, Laserscanning, Optische 3D-Messtechnik – Beiträge der Oldenburger 3D-Tage 2016,* Th. Luhmann/Ch. Schumacher (Hrsg.), Wichmann, VDE Verlag GmbH, Berlin und Offenbach, pp. 150-161

ACKNOWLEDGEMENTS

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AN OPEN PLATFORM FOR DOCUMENTING PROPERTY RIGHTS

Cadasta **Foundation**

A functioning land administration sector is the foundation of a national economy, critical for economic growth. Unfortunately, effective land registry and cadastral systems with national coverage exist in only a fraction of the world's countries. Without accurate information regarding land rights, many development goals – food security, sustainable resource management, climate change mitigation and equal rights to property for women – remain impossible to achieve, not to mention the potential for conflict when rights are not recognised and enforced.

Land tenure professionals and the larger development community have recognised that traditional approaches to recording property rights are not keeping pace with demand and remain inaccessible to the vast majority. The 2014 joint FIG and World Bank publication, *Fit-for-Purpose Land Administration*, identified the need to adapt solutions for the context, as opposed to adhering to rigid regulations for processes and accuracy. While the fit-for-purpose concept recognises the potential to collect data in a variety of ways, the challenge remains of how to document and share the resulting land information in a sustainable and cost-effective way.

Cadasta Foundation was launched in January 2015 as a non-profit organisation and, with support from from the Department for International Development (UK Aid) and the Omidyar Network, it has been working to tackle these challenges. Cadasta Foundation is developing an open platform, informed by the Social Tenure Domain Model, for documenting land and resource rights.

Through the development of an ecosystem of partners, technology and data, the platform is designed to allow the direct capture and documenting of land rights through a global open platform that is secure, cost effective and transparent. The foundation's perspective is informed by years of experience working with formal land administration processes and national-level land information systems, as well as working with volunteered geographic information to develop robust and up-to-date datasets. At Cadasta, the focus is twofold – providing the repository and tools necessary to document the rights of those left out of the formal system, while also serving as a portal for open datasets in land and other resources, such as extractives, forestry and agricultural investment concessions, where they exist.

Over the past months, Cadasta has worked with partners to test and refine the initial release of its open-source platform – working with unmanned aerial vehicles (UAVs) in Kosovo, tablets in Kenya and paper-based approaches in South Asia – to identify what partners and beneficiaries require for data collection and management. The result is a secure cloud-based platform that features customisable privacy settings, allowing users to store and back-up their data, including history. Cadasta recognises that data belongs to communities, not to Cadasta. Therefore the partners establish privacy settings, electing which projects and datasets, if any, are made public – all at no cost for use of the platform.

It is evident that data collection remains a key obstacle for many partners. As a result, Cadasta has tested and integrated with a variety of tools, including applications like Field Papers and GeoOpenDataKit, while assessing future compatibility with OpenTenure from FAO and the Mobile Application to Secure Tenure (MAST) from USAID. Finally, users can access the global image repository Cadasta streams through its agreement with Digital Globe, free of third-party claims to rights against their derivative data, in order to digitise property boundaries.

Cadasta launched its initial pilot application in January 2016 and collected considerable feedback that has informed the July 2016 release. This feedback has been critical in ensuring a user-centric design that meets the varying needs of diverse partners, recognising the tremendous diversity in technological capacity, data collection approaches and data needs. The current release features a much more intuitive user interface, improved integration with applications and support for custom data schemas. Cadasta Foundation welcomes users to test out the platform, use it in the field and provide feedback. ◂

ABOUT THE AUTHOR

Frank Pichel is chief programme officer at Cadasta Foundation. He is a land administration specialist with experience in designing, managing and implementing land-related projects with a technology focus around the globe. Cadasta Foundation provides an open platform that enables property rights to be documented and administered by the individuals and communities that own them, in concert with government land agencies where possible. Visit www.cadasta.org for more information.


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"A buddy
I rely on."
RUIDE_

BY **FRÉDÉRIQUE COUMANS**, CONTRIBUTING EDITOR, GIM INTERNATIONAL

ORDNANCE SURVEY IRELAND SHOWS NEW PERSPECTIVES, PART 2

National Mapping as a Service

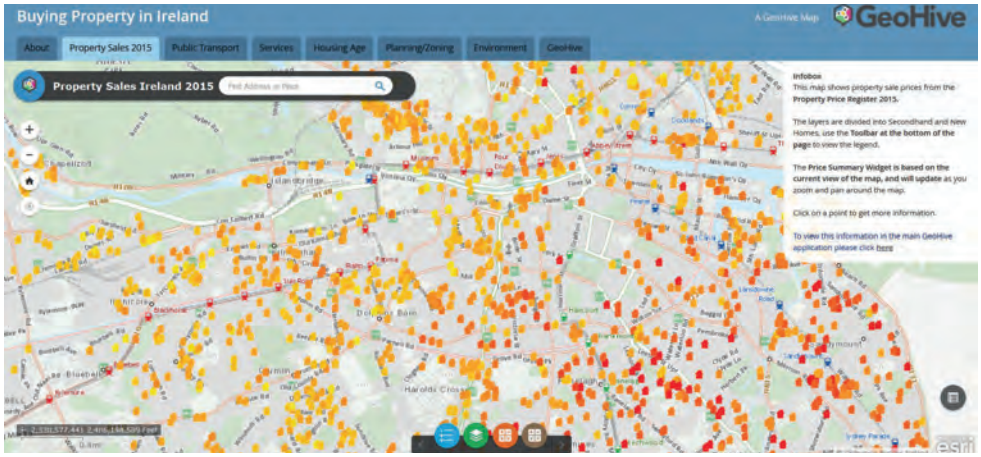
National mapping organisations from all over the world are interested to see how Ordnance Survey Ireland (OSi) is planning for its future. Not only has OSi re-engineered its work processes and implemented a multi-resolution data store to automate product and service delivery, but it has also developed a collaborative portal and is leading the way towards a National Mapping Agreement. OSi is now in the process of making 'linked data' available for all 50 million Irish real-world objects.

Ordnance Survey Ireland (OSi) has a clear technical strategy for offering national mapping as a service. In its own words, OSi wants to offer its users the streaming of "multi-resolution, spatial products and services in industry data formats from a single source of high-resolution topographic truth". The 'National Mapping-as-a-Service' strategy is one of the reasons why OSi migrated numerous legacy multi-scale databases into a single, scale-independent database known as PRIME2. It also implemented orchestrated, rule-based production workflows to enforce the highest levels of data quality, while enabling significant resource efficiencies in the various stages of data management. The newly developed data model is the foundation for OSi's Multi-Resolution Data Store (MRDS) where the data objects are brought up to date maintained once and are then automatically processed to produce a wide variety of information and products. This initiative makes it possible for OSi to be the first national mapping agency in the world that can automatically produce 1:1,000,000 cartographic products and services from its 1:1,000 topographic database. For more information about that, read Part 1 of this series on OSi in the December 2016 issue of *GIM International*.

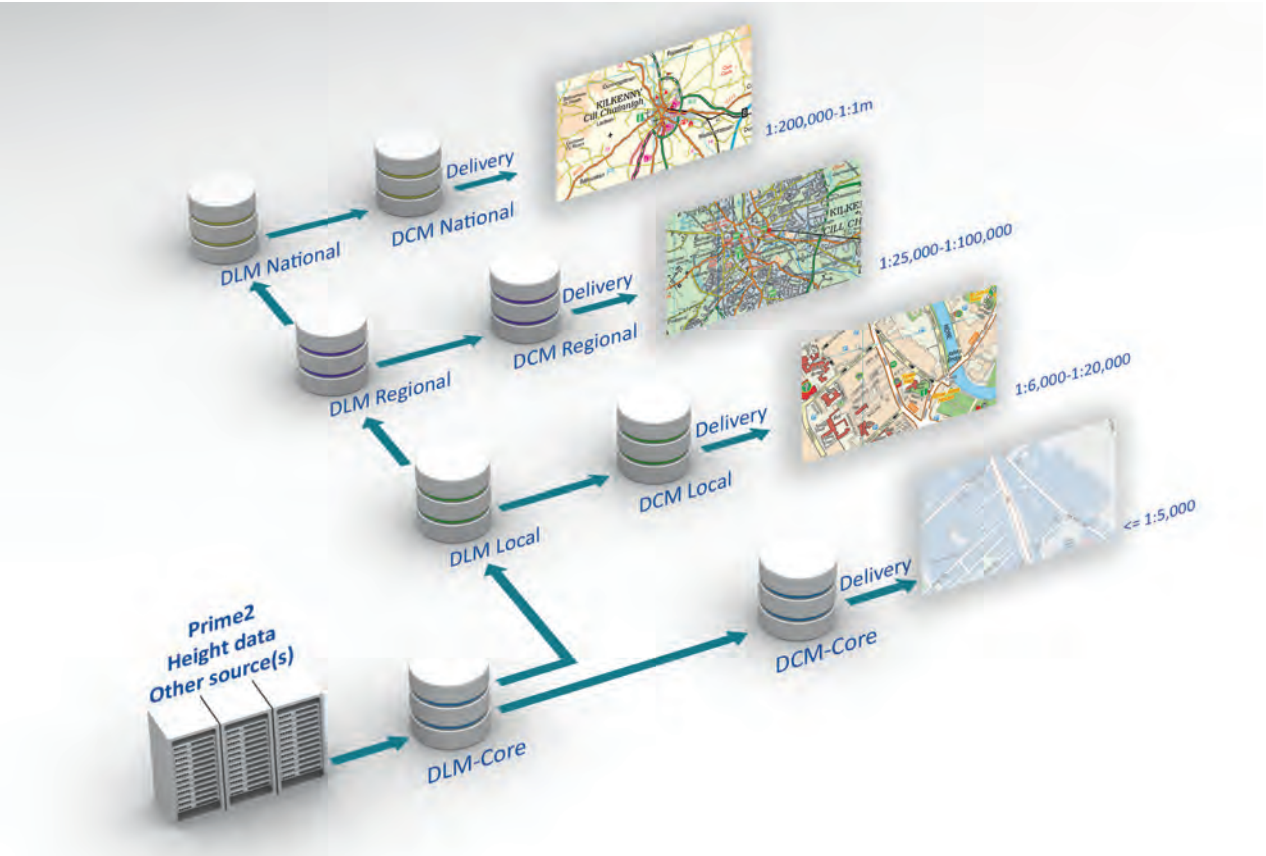
MAKE YOUR MAP

About a year ago, OSi launched a web-based geoportal called GeoHive (www.GeoHive.ie), which provides free access to Irish spatial data through a data catalogue and a map viewer. MapGenie, a commercial web-mapping service, already existed, giving both public-sector and private-sector customers access to map data. However, the use of MapGenie requires OGC-compliant GIS software or web applications, whereas GeoHive data can be queried and visualised directly.

On GeoHive, you can create maps specific to the task at hand by combining layers of location-based information from a range of public-sector bodies. Being fully responsive, the system reconfigures itself depending on the device used to open the application, e.g. either a PC or a smartphone. Colin Bray, OSi's CEO and chief survey officer, comments: "When developing this service with Esri, we chose to look from the perspective of a user with no GI knowledge and we've included user-friendly 'story maps' to show the power of combined data sources." OSi developed a tool called Make Your Map, which enables you to combine the map and authoritative data of your choice, save it on the platform for later use and share it via email and social media. You can use Make Your Map to mash up public datasets and create a map view that tells the story you need. If you are an investor, you can look at variables such as population density, industry distribution, education, journey times by mode of transport, etc. and use this information for informed decision-making, such as choosing your office location. Another application within GeoHive is to investigate where to buy property in Ireland. You can evaluate and compare different locations by analysing transport systems, average house prices, schools, hospitals, housing age, planning zones, etc. "If people think that different stories can be told, or if the stories could be better told by using additional datasets, then we are very open to receiving suggestions," states Bray.



▲ *You can use Make Your Map to mash up public datasets and create a map view that tells the story you need.*



▲ *With the Multi-Resolution Data Store (MRDS) data objects are maintained once and then automatically processed to produce a wide variety of products.*

"If we see a topic in the media that can be better explained with spatial information, we will look at what other publicly available datasets are out there and bring them together to tell the story." At a technical level, GeoHive uses the functionality of ArcGIS Online as its content management system for listing and categorising web services.

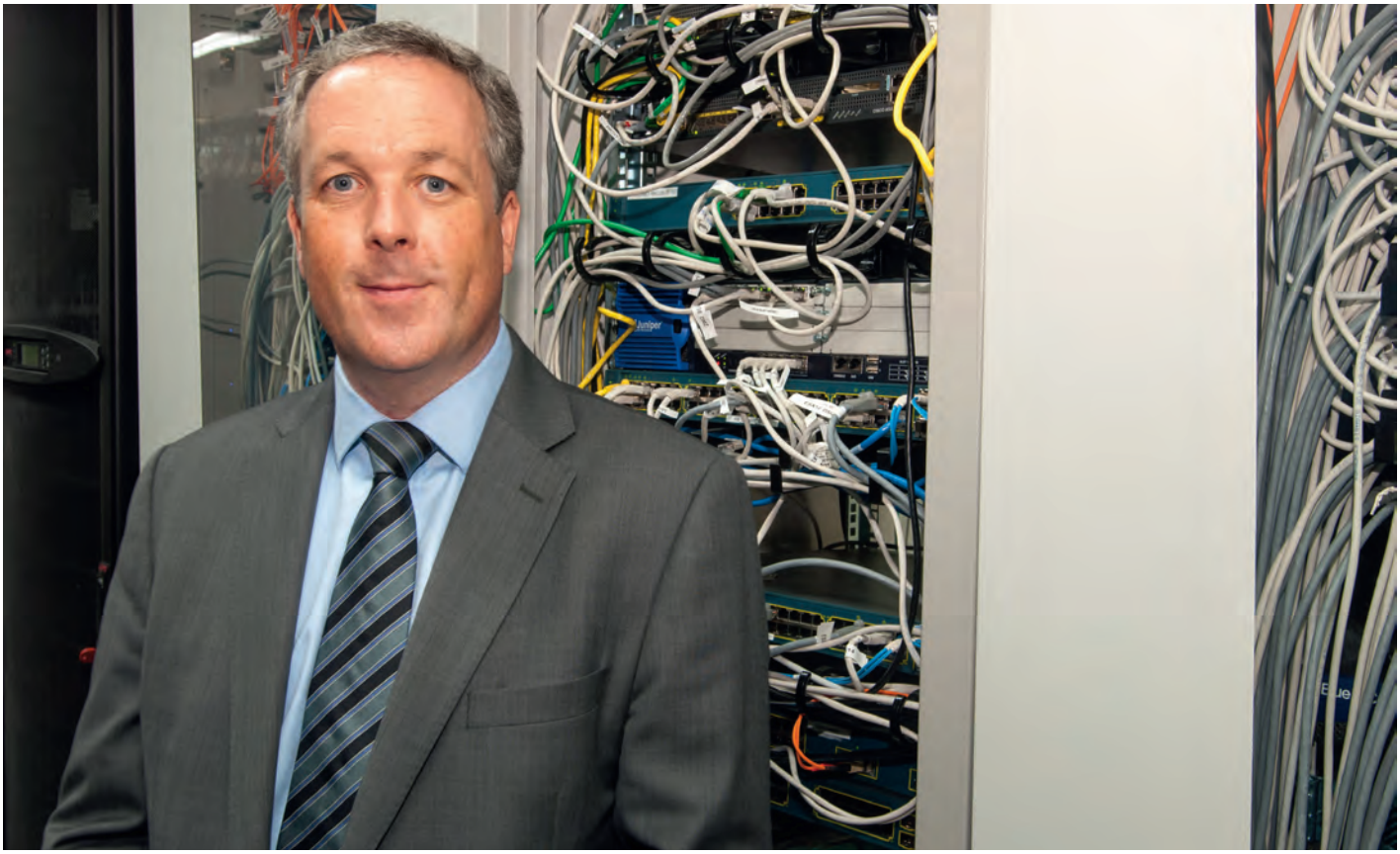
LINKED DATA

The changing world of content delivery offers new perspectives for OSi's mapping-as-a-service strategy. The organisation has been working with the ADAPT research Centre at Trinity College, Dublin, on the creation of a linked spatial data management model. 'Linked data' marks a shift from human-readable HTML documents that are connected via hyperlinks to machine-readable documents that allow for connections of data between web systems across the globe. The publication of OSi's geospatial data as linked data on the web enables third parties to explore and consume the data via a combination of simple, standardised technologies, such as Unique Resource Identifiers (URIs) that operate over the internet's existing HTTP infrastructure (a URI identifies a resource either by location or by name, or both). The data is available both via Triple Pattern Fragments Server and Web Client, a linked-data front end (e.g. by following the HTTP URI of county Dublin) and as downloadable datasets for local use. OSi's PRIME2 database is made up of over 50 million uniquely referenced geographic objects, and many of them will have URIs in due time.

OSi has created a new linked data standard for high-resolution geometry: the Geospatial Linked Data Standard. Bray explains: "The existing standards were not good enough for large-scale spatial data when part of the geometry changes. Users must be able to drill down, getting different resolutions of the data, going from seeing a hundred objects to one aggregated object in seconds. Those objects need to be able to link back to the source. And that is what this new standard is doing."

But everything can't be done at once. Therefore, because administrative boundary data has enormous relevance to many public organisations, OSi chose to make that available as linked data first. Via the dedicated Linked Data platform (www.data.geohive.ie), third parties can consult authoritative administrative boundary data and develop novel applications on top of it. For example, the Linked Data platform could be used to access Irish administrative boundary data and then to combine it with the 2011 Census data, which has been published by the Central Statistics Office as open-source linked data. Additional datasets are being made available and new stories will be told.

WE HAVE TO MAKE SURE THAT ALL PUBLIC ORGANISATIONS TALK ABOUT THE SAME OBJECTS AND THE SAME 'SOMEWHERE'



▲ *Colin Bray: "OSi has created a new linked data standard for high-resolution geometry. Users can go from seeing a hundred objects to one aggregated object in seconds." Photo: courtesy Jeroen van Berkel*

NATIONAL MAPPING AGREEMENT

GeoHive and the linked data initiatives support the Irish Public Sector Reform Plan 2014-2016. Under this plan, OSi was asked to develop a national spatial data strategy and to create a National Mapping Agreement to ensure that a national geospatial platform can be released for the public sector. This indicates central government's recognition of the importance of geographic information. Bray expects the National Mapping Agreement to come into effect in 2017. "That will enable us to open up all of our data to the public sector under a centralised licensing agreement. Mapping is not just about locations anymore – nowadays, it's about objects. We had 5,000 map sheets that described the large-scale data for Ireland, and we now have a single database with millions of unique objects. Each of those objects has a location reference. We have to make sure that all public organisations talk about the same objects and the same 'somewhere'. That's why part of the developing national strategy needs to be education and awareness, and we will support our colleagues in their transformation."

THE NEAR FUTURE

An initial study showed that the use of geoinformation in government saves EUR82 million per year in running costs. "And that's a conservative figure, based on the current, limited use. So we intend to undertake another study in three years' time, when our data platform is further embedded in government planning and decision-making. We foresee further quantifiable cost savings and efficiencies for government from the use of a national standards-based geospatial platform," says Colin Bray. "There are already many more users than in previous years who take our data as an interactive layer in their own systems. At the end of the three-year period, we want to be the national providers of trusted, maintained spatial data and platforms. We want to be the enablers making the state's spatial data easy to find, share and use."

In Bray's view, OSi supplies the state with an authoritative geospatial platform, but the maintenance of the databases will continue to be based on a federated approach. For example, OSi collects the road geometry but the National Roads Authority provides the attribution. "The types of objects, features and details will grow, but we don't have to do everything ourselves. As for our own database, we are now preparing to update it in 3D. We also need to consider the inside of buildings and see how we integrate with the concepts of building information modelling (BIM) and of mapping below ground – not only what is visible. Technology will give us directions in what is doable, as it has always done in the past." ◀

OUTPUT

Besides MapGenie and GeoHive described here, there is also Geoportal (www.geoportal.ie), which is a shared government resource, developed and maintained by OSi, designed to facilitate the viewing and downloading of spatial data according to the requirements of the EU INSPIRE Directive. All EU countries have such a national portal for their core national reference datasets. Ireland additionally has the national portal www.data.gov.ie, on which OSi has over 50 open datasets.

Ordnance Survey Ireland is Ireland's national mapping agency, a state body. Its funding model is made up of commercial revenue (81%) and national interest mapping (19%). 60% of its commercial income comes from the public sector.

RACURS CONFERENCE

Russian Focus on the World

The Russian geospatial software community, with at its forefront Racurs, is regaining a leadership position amongst the world's other big software communities. The software packages on offer are renewed and up-to-date and able to compete with the best. Each year, together with its flagship product Photomod, Racurs gives members of the community a chance to catch up with other users, company engineers and business leaders alike, at the annual conference called 'From Imagery to Map'.

Photogrammetric software supplier Racurs fixed its sights on India in 2016 as the location for its 16th International Scientific and Technical Conference, 'From Imagery to Map'. The conference was held in the old Moghul city of Agra in the northern state of Uttar Pradesh from 14-17 November 2016.

Numerous geoexperts and academics, clients, entrepreneurs and other professionals gathered together at the Gateway Hotel. For Russians and their business partners, the social aspect of doing business is almost just as important as the technical conference and the beautiful hotel was the perfect venue in that respect.

GROWTH

Director and co-owner Dr Victor Adrov mentioned to *GIM International* that Racurs had previously lost its share in the Indian market, but that the conference and a new partner in India are opening up opportunities to gain ground in that massive market once

▲ *Delegates visited the iconic Taj Mahal, a UNESCO World Heritage site.*

again. Other growth markets for Racurs certainly include the organisation's home base of Russia, but also China and other parts of Southeast Asia. Fields of application that holding potential for Racurs are forestry and environmental monitoring, and of course all models built up by data gathered using unmanned aerial vehicles (UAVs). Racurs' software is equipped to support this type of data, as it is compatible with all data coming from Russian, Korean, Vietnamese and Chinese satellites and not just from the better-known imagery providers like Digital Globe and Airbus. Learn more about Dr Victor Adrov's views on the market and why he is focusing on India by watching this video: https://youtu.be/eglSv1IG4PQ.

TECHNICAL PROGRAMME

The conference in Agra offered a full technical programme. On the first day the focus was on aerial and UAV surveying, 3D modelling and common geomatics problems. Environmental monitoring is one of the hottest topics in the industry at the moment and Professor Emeritus Grün from the ETH in Zurich, Switzerland, certainly captivated the audience with his presentation about the physical ecosystem modelling on the tropical island of Moorea Avatar, part of the French Polynesian Territories. Natalia Vorobyova, head of department at Russian UAV supplier Finko, presented on the applied significance of unmanned aerial system (UAS) data processing, and Alexey Smirnov, technical support manager with Racurs, took the delegates on a trip down memory lane to show the amazing progress of UAS data processing over the years.
The second day of the conference focused on the new technologies of remote sensing data processing. Delegates were treated to a host of very interesting presentations by business leaders including Wook-Hyun Choi, vice president of SI Imaging Services from Korea, but also Vyacheslav Butin of Sovzond Company from Russia and Valery Zaichko, head of department at ROSCOSMOS, the Russian State Space Corporation.
Most of the third day of the conference was spent in business meetings and roundtable sessions where the delegates entered into lively discussions on the themes of 'Remote sensing – from UAS to satellite: optimal image acquisition strategies' and 'New ways of photogrammetry'. In both round roundtable sessions one could sense the dynamism of the industry and the excitement about the future of photogrammetry and its many applications.

AUTHENTIC INDIAN ATMOSPHERE

In addition to a focus on the exchange of technical experiences, learning and sharing, the social aspect is another very important ingredient of every Racurs conference and this edition was no different. The week started with a tour of the Taj Mahal, a UNESCO World Heritage site and probably one of the most iconic buildings in the world. The conference was concluded with a day of excursions. Fatehpur Sikri, Jodha Bai's Palace, was the first stop: a fort and mosque stemming from the Moghul time. The second stop was the Hare Krishna sanctuary on the way from Agra to Delhi, where the visitors could briefly immerse themselves in that eastern religion. On the days of the conference itself, the delegates were treated to yoga sessions, Indian cooking classes and a real Maharaja-style dinner in a palace for one day, built up in the gardens of the hotel. For a lot of the delegates who had never been to India before, the conference was a cultural revelation. There is no denying that the heartbreaking poverty that is prevalent in the country is often a shock to first-time visitors. Although inconvenienced by the current rupee crisis resulting in long lines at every bank in the city and the country for days, the delegates were humbled by the fact that the local people face much bigger problems. But despite the country's issues, the delegates thoroughly enjoyed this in-depth introduction to the Indian lifestyle, eating habits and music. ◀

▲ *View of the gardens of the conference hotel in Agra.*

Go to conf.racurs.ru/conf2016 to see the full programme, read papers and watch videos of presentations.
For all technical specifications of Racurs' products, go to www.geo-matching.com.

AEROMETREX GROUP

Aerial **Survey Innovators**

Supercharged by massive amounts of digital aerial imagery and the 'new' photogrammetry, Aerometrex Pty. Ltd. is an Australian aerial survey company on the rise. With headquarters in Adelaide, South Australia, a Lidar operation based on the Sunshine Coast in Queensland and a number of sales reps across the country, Aerometrex is now a truly national service provider covering 7.7 million square kilometres of territory.

Aerometrex was first registered in Queensland, Australia, in 1980. The company has been headquartered in Adelaide since 2000, beginning with a handful of staff. Aerometrex's average annual increase in turnover since 2005 is 18% per annum, a creditable performance in markets which have sometimes neared recession conditions. The current incarnation of the company is the result of a management buyout in 2011 and the workforce current numbers over 50 employees. The staff-management ownership of the company has been a very positive factor in the growth of the enterprise over the last five years. Aerometrex's board of directors includes four staff members who have senior management roles in the company as well as an external CFO.

The acquisition of the Atlass Lidar business in Queensland in September 2015 has provided Aerometrex with a complete suite of aerial surveying capabilities. Atlass-Aerometrex is very active in the coal mining sector as well as construction and engineering, road surveys and environmental surveys. Aerometrex's services now include aerial photography, all aspects of photogrammetry including orthophoto production, digital terrain models and stereo-digitising as well as advanced 3D modelling (aero3D service), Lidar surveys and visualisation technology.

INVESTMENT: THE PATH TO GROWTH

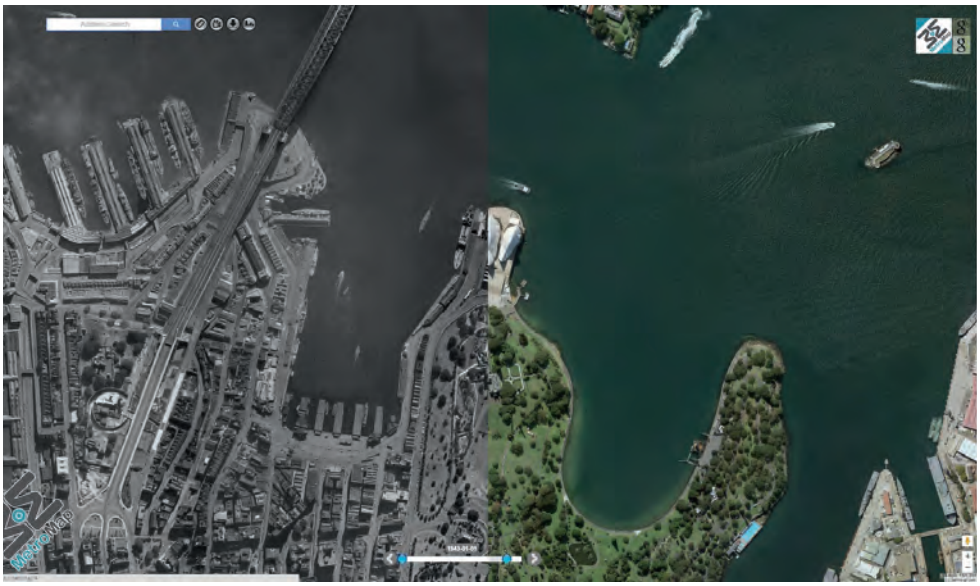
Aerometrex's management philosophy is one of steady organic growth utilising local staff, making investments in new sensor technology and also investing in an innovative research and development (R&D) programme. The company has made significant investments in state-of-the-art camera technology in recent years, including an Ultracam Eagle Prime camera and a Visionmap A3 Edge camera.

R&D PROGRAMME

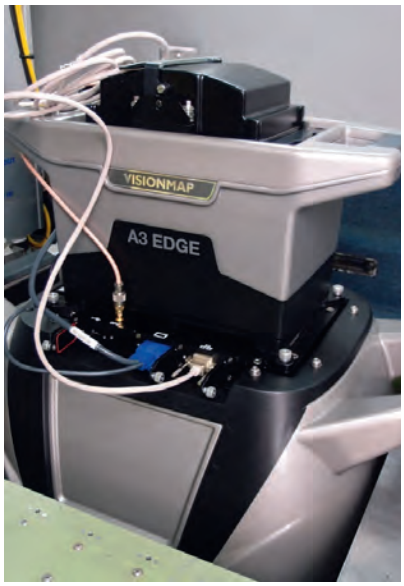
The R&D programme delivered Aerometrex's world-leading 3D modelling service, aero3D, in the first 12 months of new ownership in 2012. This method utilises the 'new' photogrammetric technique of massive multi-ray matching to generate very-high-resolution, photo-realistic 3D models. The resolution of these models is typically 2 to 3cm ground sample distance (GSD), and accuracies of better than 50mm in XYZ can be obtained with GPS ground control. Aerometrex has also established MetroMap, a web-based delivery mechanism for the company's expanding archive of aerial orthophoto imagery. Every mainland capital city of Australia is now covered with MetroMap imagery.

INTERNATIONAL EXPOSURE

Up until recently, the company's experience in servicing international markets had been limited to working close to home in New Zealand and Papua New Guinea. However, aero3D has attracted worldwide attention. Mark Deuter, managing director of Aerometrex, comments: "The market for 3D modelling is unprecedented in our industry.



▲ *Sydney side-by-side comparison from 1943-2015 in MetroMap.*



▲ *Visionmap A3 Edge in Aerometrex's aircraft.*

There is a very wide range of applications. We provide 3D models to engineers and surveyors for measurement applications as they are approaching survey-grade accuracy. But there is also nothing like these models for visualisation and communication of a concept to the general public. People instantly 'get' 3D. We have been pleasantly surprised at the breadth of interest we have generated from our YouTube video gallery."

Aerometrex is able to provide the aero3D service anywhere in the world with relatively low mobilisation costs. For example, in conjunction with Bentley Systems, the company captured imagery and generated 3D models for the City of Philadelphia in the USA to facilitate the visit of Pope Francis to the city in September 2015. The 3D models were used for event planning and security.

▲ *Sydney 3D city model.*

IN-HOUSE VERSUS OUTSOURCING

Aerometrex has a policy of performing all skilled work in-house. The company takes the view that it is not possible to control quality, to meet deadlines, to preserve and refine skills and to drive innovation if core work is outsourced. While this may be at odds with practices elsewhere in the industry, the company believes strongly that it serves its clients best by doing the work in-house. It is also acutely conscious that to develop and pass on skills in the industry it must train new staff in all aspects of the enterprise. This is a vital part of the long-term succession plan to be able to leave the company in good hands.

▲ *The Aerometrex team.*

THE NEAR FUTURE

Regarding likely future developments, Mark states: "One thing we expect to see is a rapid transition from 2D to full 3D mapping systems during the next five years, and exclusive use of 3D by 2026. Flat maps, elevations, profiles and suchlike have served us well for millennia, but they are an abstraction of the real world. 3D is much more intuitive and is already present in nearly all computer games! One thing we actually don't foresee is a takeover of the aerial survey industry by unmanned aerial vehicles (UAVs). UAVs are very small platforms with small payloads and small sensors, so they are really only suited for very small projects. The market will eventually sort out the costs and benefits of the various aerial surveying methods."

LONG-TERM OUTLOOK

Aerometrex is well positioned to take advantage of the next rising cycle of global economic activity, as well as a recovering Australian economy. It has a wider client base than ever before, a full suite of aerial surveying capabilities and a skilled workforce. The company believes there has never been a more exciting time to be involved in this industry and is looking forward to the challenges of the 2020s and beyond.

Every month *GIM International* invites a company 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.

From Volume to Quality: Bridging the Gap for Spatial Data Infrastructure

The participants at the Opening Ceremony of Commission 3, Geomat and EGoS.

FIG Commission 3 organised its Annual Workshop in Iasi, Romania, from 3-7 November 2016. The theme of the event was 'From Volume to Quality: Bridging the Gap for Spatial Data Infrastructure'. The focus was on the role of geographic information systems in relation to the correct approaches of managing spatial data over the internet. The 'gap' results from the processing of large volumes of spatial data in the informatics environment, often uncontrollably.

The gap must be filled by an appropriate approach to assure users of the reliability of spatial information in order to prevent incorrect decisions. The exchange of knowledge between the various members will also facilitate the synergy between public administrations that fulfil specific activities on a territory: from urbanism to spatial planning, from the environment to civil defence, from roads to construction, from agriculture to forestry, and from tourism to culture.

This workshop explored ideas and methods on how we can engage citizens through crowdsourcing within reliable new models of collaboration. The workshop was an opportunity for delegates to present their research and experiences in the field of development and use of volunteered geographic information, geographical information systems, spatial information management and spatial data information procedures.

As best paper was elected 'Rectilinear Approach to 3D Generalisation of Building Models' by Alexey Noskov and Yerach Doytsher (Israel). The workshop was organised jointly with the International Symposium Geomat 2016 and with the EGoS General Assembly by the Department of Surveying and Cadastre, Faculty of Hydrotechnics, Geodesy and Environmental Engineering from Technical University of Iasi and co-organised by the Romanian Association of Romanian Surveyors.

By Enrico Rispoli and Maria Scorza, FIG Commission 3

FIG WORKING WEEK 2017, 29 MAY – 2 JUNE 2017 IN HELSINKI, FINLAND

The overall theme for the Working Week 2017 is 'Surveying the World of Tomorrow – from Digitalisation to Augmented Reality'. One step is to become digitalised and to use the digital information; the next step is to combine information and be able to collect the data intelligently and to take further steps into the intelligent use of digital information. The theme has been chosen to highlight the opportunities and open a view into a future where the large amount of information we produce is put to even more efficient use. Registration has now opened: www.fig.net/fig2017

JOINT FIG-GLTN-OGC EVENT IN DELFT, THE NETHERLANDS, MARCH 2017

A joint event of the International Federation of Surveyors (FIG), the Global Land Tool Network (GLTN) and the Open GeoSpatial Consortium (OGC) will be organised in Delft, The Netherlands, on 16 and 17 March 2017. A GLTN/FIG workshop will focus on the development of requirements and proposal for land administration operational standards and for the second edition of the Land Administration Domain Model (LADM). Possible extensions of the LADM ISO 19152 are in marine cadastre, fiscal cadastre, modelling of rights, restrictions and responsibilities, in linking to land and in building information modelling (BIM). An OCG workshop will discuss relevant input for consideration by OGC for the development of operational domain standards for land administration.

More information
www.fig.net

Summary of GSDI 15 Conference in Taipei

The 15th Global Spatial Data Infrastructure World Conference (GSDI 15), held in Taipei, Taiwan, from 29 November to 2 December 2016, attracted participants from 44 nations to share their experiences and discuss the future development of spatial data infrastructure (SDI) and smart territories.

The conference featured 110 presentations in 24 technical sessions, plus 20 workshops covering a wide range of topics related to the conference theme, 'Spatial Enablement in the Smart Homeland'. The breath of presentations revealed the complexity of what constitutes SDI. Presenters looked beneath

the surface of SDI and explored its historical underpinnings or addressed evolving methods for data collection and inter-operability. Many focused on sophisticated web applications and location-based analytics related to the conference sub-themes, 'Smart Disaster Prevention', 'Smart Transportation' and 'Smart City'. Several presentations brought home the disparity in SDI capacity across the globe. Colleagues in Mongolia and Zimbabwe spoke of long-standing challenges with respect to data sharing, policy and funding, while countries such as Taiwan are moving at lightning speed, developing new ways to use data and technology to serve individuals, communities and society.

The disparity points to the role that the GSDI Association can play in closing the implementation gap. Furthermore, the repeated mention of a 'need for collaboration' throughout technical sessions and workshops indicates the value of greater critical assessment of the effectiveness of current data strategies, work flows and institutional behaviour. Plus, there are obvious tie-ins for improving SDI implementation through alignment with Sustainable Development Goals (SDGs), open data initiatives and other processes at national and local levels.

The 20 sponsored workshops were a highlight of the conference, addressing SDI concepts and challenges in greater depth. A special session with winners of the Group on Earth Observations (GEO) travel grant awards from Philippines, Indonesia, Kenya, Ukraine and Uganda provided insights into how developing and emerging countries are grappling with SDI components in varying political, administrative and cultural contexts.

The extensive exhibition showcased cutting-edge drones, robots, sensors, software and web applications designed to harness the assets of cities, advance a cross-functional, transportation ecosystem and interact with citizens to mitigate risk and increase safety. It was the largest gathering of the geospatial industry that Taiwan has seen thus far.

Special thanks and appreciation for supporting GSDI 15 goes to the Silver Sponsors, Esri and the National Chung-Shan Institute of Science and Technology (NCSIST), as well as the Ministry of Interior. The members of the Local Organizing Committee led by the Taiwan Association of Disaster Prevention Industry (TADPI) are to be heartily congratulated for making GSDI 15 a great success. The conference website remains at http://gsdi15.org.tw/, but will be archived with updated final material at http://gsdiassociation.org/.

The GSDI 15 exhibition.

More information
www.gsdi.org

Report: Gravity Geoid and Height Systems Symposium

The Gravity Geoid and Height Systems Symposium 2016 (GGHS2016) meeting was the first Joint IAG Commission 2 and IGFS Symposium co-organised with GGOS Focus Area 1 'Unified Height System'. It took place in Thessaloniki, Greece, from 19-23 September 2016 at the Aristotle University of Thessaloniki. The symposium's focus was on methods for observing, estimating and interpreting the Earth gravity field, as well as its applications.

GGHS2016 was organised in 6 sessions:

1. Current and future satellite gravity missions
- Improvements in GRACE data processing are still being achieved, which generates increasing interest in using GRACE products for drought/flood forecasting and other applications. Hence there is concern about continuity beyond the GRACE-FO mission. GOCE data is leading to improved understanding of time-varying environmental parameters with gravitational signatures.

2. Global gravity field modelling
- New modelling developments regarding high-resolution global gravity models indicate significant improvements in accuracy. New data products (e.g. Antarctic polar cap, high-resolution marine gravity field) have become available, and innovative observation concepts based on relativity and quantum optics are being developed.

3. Local/regional geoid determination methods and models
- Major improvements in computational techniques have been made. Further improvements have been achieved in the activities of the IAG sub-commissions on gravity and geoid, e.g. in Europe and Africa.

4. Absolute and relative gravity: observations and methods
- Highlights of innovative observations technologies have been presented, such as measurement results from test campaigns with a new French transportable quantum gravimeter. Very good and robust results from strap-down airborne gravimetry with a German system, flown side by side with a traditional Lacoste-Romberg sensor, have been achieved.

5. Height systems and vertical datum unification

- Important considerations for the realisation of the International Height Reference System, especially determination of potential values, time-dependent changes and consistency with the geometric coordinates, have been made. Strategies for the combination of different geodetic data (GNSS/levelling, gravity, Global Gravity Models, tide gauge registrations, Mean Dynamic Topography) for the vertical datum unification have been presented.

6. Satellite altimetry and climate-relevant processes

- Altimetry improves in precision due to new sensors and new geodetic missions, advancing our understanding particularly in coastal and arctic regions, which together with GOCE data brings new knowledge to oceanography. New insights and refined understanding of mass transport processes on various timescales have been gained, and advances in computational methods for GRACE and future gravity missions have been made.

94 papers were scheduled as oral presentations and 117 as posters. All accepted papers may be submitted for the peer-reviewed IAG Symposia Series published by Springer Verlag. There were 204 participants from 36 countries, with 35% of participants being graduate students.

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

Looking Both Back and Forward

The Commission on the History of Cartography was re-approved by the ICA General Assembly in 2015, under the leadership of Prof Imre Demhardt, University of Texas, Arlington, USA. A distinguished scholar of 19th-century cartography and associated topics such as colonialism and tourism, Imre has led several conferences and published widely in the past. Associated with the 28th International Cartographic Conference in Washington DC in July this year, Imre and his Commission will be organising a pre-conference workshop called 'Charting the Cosmos of Cartography: History – Names – Atlases'. This joint meeting with sister ICA Commissions, on Toponymy and on Atlases, will be held at the Library of Congress (Madison Building) from 28 to 30 June 2017. Through the Commission's website (http://history.icaci.org/), papers are invited (deadline 15 February 2017) on topics relating to these themes.

L'Enfant's 1792 plan for Washington DC.

The Commission activities continue in 2017 with a joint symposium with Leiden University Libraries on 'Mapping Asia: Cartographic Encounters between East and West', to be held from 15-16 September 2017. The central theme of this meeting is the mutual influence of Western and Asian cartographic traditions, with a focus on topics related to India, China, Japan, Korea and Indonesia. Papers are invited for this symposium by the deadline of 15 February 2017 (http://history.icaci.org/leiden-2017/). During the symposium, Leiden University Library will present several exhibitions from its Asian collection including the Bodel Nijenhuis Collection (large numbers of historical Dutch East Indies maps), the Indonesia collection which has many maps of the 19th and 20th centuries and includes the collections from the Royal Tropical Institute (KIT) and the Royal Netherlands Institute of Southeast Asian and Caribbean Studies (KITLV), the Siebold collection with a Japanese specialism, and the map collection of the Sinology Institute. The symposium will be held within the framework of the 'Leiden Asia Year'; the new Asian Library will open on the roof of the Leiden University Library on 14 September 2017, just before the symposium starts.

The proceedings of both these meetings will be published in due course, to join the previous well-documented contributions from earlier conferences. Lately published by Springer, these archives form a valuable body of knowledge relating to global 19th and 20th-century cartography in particular.

More information
www.icaci.org

ISPRS Geospatial Week 2017, 18-22 September, Wuhan, China

Building on the success of the previous Geospatial Week held in France in 2015, the ISPRS Geospatial Week 2017 (GSW 2017) will take place on from 18-22 September 2017 in Wuhan City, one of central China's largest modern metropolises. Wuhan University will be the organiser of GSW 2017 with support from other local research institutes and universities.

GSW 2017 will feature tutorials and forums, with workshops covering a range of subjects including photogrammetry, remote sensing and geospatial information science, along with sessions focusing on emerging topics including smart city, geospatial big data, UAVs, remote sensing at night, laser scanning, 3D modelling and indoor navigation, image fusion, data mining, SAR/

InSAR and more. No matter what your research interests are, you will find them discussed and reported at GSW 2017.

GSW 2017 will also organise technical exhibitions and many social events. A one-day or two-day technical tour to the Three-Gorges Dam will explore the engineering marvel of the first huge dam on the Yangtze River, the longest river in the world. The Hubei Provincial Museum, within walking distance of the conference centre, displays artifacts attesting to the splendid culture that has emerged in central China over thousands of years. The Han Show presents mixed modern Chinese culture in two hours, with traditional Chinese culture blended with latest technology.

GSW 2017 is designed to appeal to a diverse audience from all over the world. The award categories include best paper and best poster. To encourage young people from developing countries to join this event, GSW 2017 will also set up a funding programme to help support their participation.

Wuhan University campus, central China.

With the most beautiful campus in China and as the largest centre of higher education in photogrammetry, remote sensing and geospatial information science, Wuhan University is looking forward to welcoming researchers, professors, students and industrial practitioners to GSW 2017.

By Deren Li, GSW 2017 director
Professor and academician of CAS and CAE

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.

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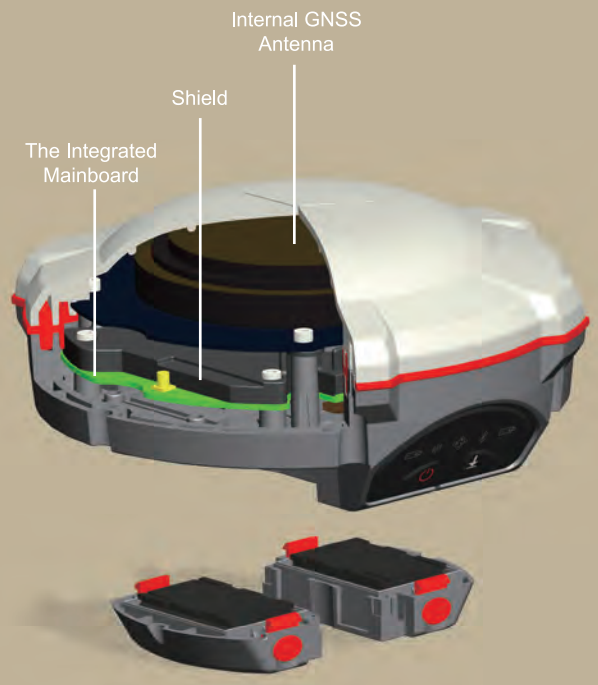

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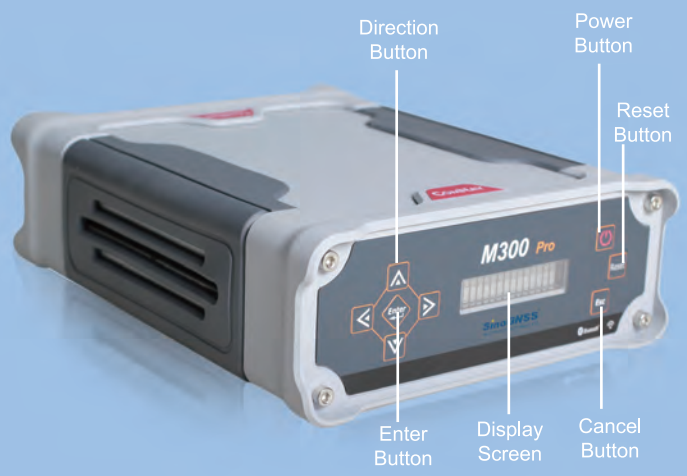

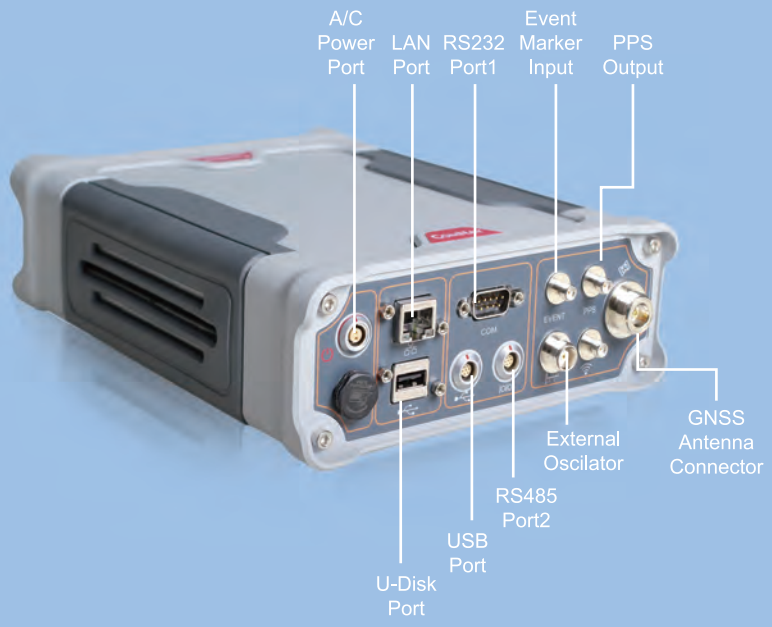

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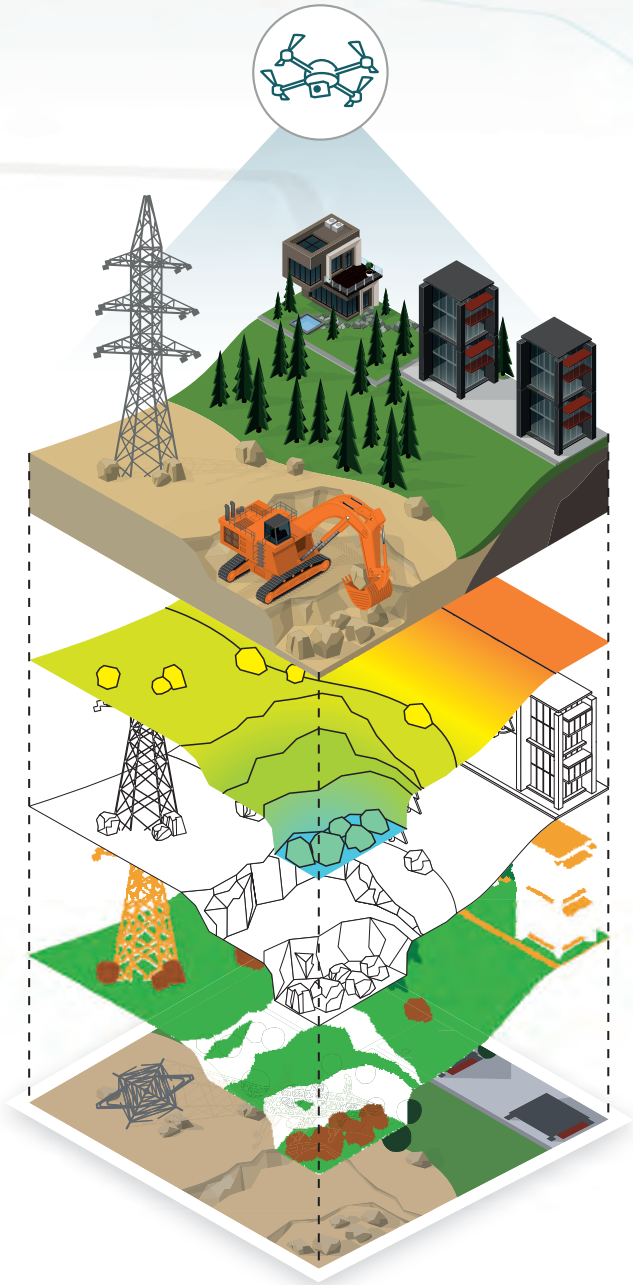

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