VOLUME 14 ISSUE 3

LIDAR MAGAZINE

FALL 2024

SPECIAL ISSUE

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SENSOR SPOTLIGHT 2024

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Vexcel Imaging, headquartered in the beautiful city of Graz in Austria, is familiar to most readers. Its high-performance aerial cameras, UltraCam Eagle 4.1, UltraCam Osprey 4.1, UltraCam Condor 4.1 play hard in the global market, supported by UltraMap software. Vexcel Imaging's announcements of sales successes figure prominently on our website. At INTERGEO in Berlin in October 2023, however, Vexcel Imaging made two dramatic product announcements. The first was the UltraCam Merlin, based on Bayer pattern sensors rather than a panchromatic channel to pan-sharpen the RGBN. The second brought Vexcel Imaging vividly into LIDAR Magazine's bailiwick.

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26 A Digital Twin for Nottingham

As urban environments continue to evolve, local authorities require increasingly comprehensive and accurate geospatial data to inform governance, planning, and communication with their communities. Smart city initiatives are making this happen by harnessing the power of reality capture to generate digital twins of entire cities. One example is the city of Nottingham in the UK. With increasing national demand to see cities in 3D and digitize planning processes, Nottingham City Council set out to develop a digital twin of the city. Using data captured from hybrid airborne sensors to create a 3D model, they were able to transform…

BY ADINA GILLESPIE AND LAYTON HOBBS

48 Elevations for the Nations (Part II)

Mapping activities for the United States are centrally regulated for a land area of 3.8 million square miles, whereas lidar coverage of Europe's 3.9 million square miles is managed at the national level, by 50 different countries. This approach has resulted in varying levels of coverage: some areas boast extensive lidar data, while others are still in the early stages of implementation, as explained in the first part of "Elevations for the Nations". To gain a comprehensive understanding of lidar mapping across Europe, the European Association of Aerial Surveying Industries (EAASI) reached out to representatives from national mapping agencies on the continent.

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BY DR. STEWART WALKER

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Textured 3D mesh of London, England (from both nadir and oblique images). Developed through a digital surface model (DSM), oblique imagery to provide texture, oblique DSM, and true ortho. Representation courtesy of Vexcel Imaging.

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DR. A. STEWART WALKER

Sensor Integration Celebration

Considerate of this edition's wide-scale distribution at Intergeo 2024, held in Stuttgart, Germany on 24-26 September, we have endeavored to imbue the following pages with some European flavor. On page 48 you'll find part II in the series "Elevations for the Nations" by Ada Perello of EAASI[1], reporting on five more countries' approaches to national elevation datasets. Two of them, Belgium and UK, have regional solutions, so it's a complex picture.

A quick note regarding this month's coverstory: in 2022, I visited Vexcel Imaging in Graz, Austria, after the ISPRS Congress in Nice and the YellowScan "LiDAR for Drone" user conference near Montpellier, on the way to my unforgettable day at RIEGL in Horn, Austria. I spent a morning with CTO Dr. Michael Gruber, who showed me round and discussed Vexcel Imaging in depth. Impressive though its airborne cameras were, there was no direct lidar connection. Now there is. At Intergeo in 2023, Vexcel Imaging announced a new product, UltraCam Dragon 4.1, which incorporates a RIEGL VQ-680 OEM 2.4 MHz lidar sensor, integrated into the same housing as the RGBN camera system. Previously, Vexcel Imaging customers had flown separate lidar sensors in their aircraft alongside the cameras, but now they can work with a single sensor—a world-class integration, indeed. Secondly, Michael retired recently, having been a company stalwart for 30 years. We should honor his contributions.

Beginning on page 26, we offer an account by Adina Gillespie and Layton Hobbs of Hexagon describing the creation of a digital twin of the city of Nottingham in England. The end-users are departments of Nottingham City Council and the beneficiaries are the citizenry. It's enthralling to learn about further data being added to the digital twin, which is based on the imagery and lidar flown by Bluesky International (5 cm/30 ppsm), and how the digital twin is being used.

The Nottingham digital twin is above ground. This could change. The Brits have become concerned that a hole is dug every seven seconds, threatening the web of underground pipes and cables, about which information is scanty[2]. There are 60,000 strikes per year, costing $3.1bn. Whereas the national mapping agency, Ordnance Survey, has been making superb maps since the 18th century, there has been no corresponding subterranean responsibility. Hence the Geospatial Commission is promoting a National Underground Asset Register, a digital map of the trenches, cables and pipes that lie beneath Britain.

1 European Association of Aerial Surveying Industries: eaasi.eu.
2 Anon, 2024. What lies beneath: subterranean assets, *The Economist*, 452(9410): 42, 17 August 2024.

LIDAR MAGAZINE

www.lidarmag.com

2024 Vol. 14 No. 3

LIDAR Magazine is published 4x annually by Spatial Media LLC. Editorial mailing address: 7820 B Wormans Mill Road, #236 Frederick, MD 21701. Tel: (301) 668-8887; Fax: (301) 695-1538.

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YellowScan

The project began in 2019 as a pilot in London and the north-east of England; it should cover the whole of Britain by the end of 2025. It's voluntary, however, so who will contribute? Who will have access? Is this a nationwide opportunity for ground-penetrating radar?

Readers may remember a recent article on standards and guidelines by Qassim Abdullah[3]. I am delighted to report that Marc Cheves, editor emeritus of our sister magazine, *The American Surveyor*, admired it as much as I did and has published it too[4]. Marc particularly liked Qassim's clarification of nomenclature, especially the term "absolute accuracy". Thank you, Qassim.

Leafing through the latest issue of *xyHT*, I was pleased to see an article about Italian supplier Stonex[5]. It is active in North America and its huge portfolio includes lidar. Stonex attends most trade shows, so some background is useful. I was drawn particularly, however, to the caption of one of the graphics, which reads, "Stonex emphasizes repair, service and support." Earlier the same day, I had enjoyed recording one of *The LIDAR Magazine Podcasts*, on which my guest was Dr. Tristan Allouis, CEO of the French UAV-lidar integrator YellowScan. Tristan used almost exactly the same words! He also described the development of the topobathymetric sensor that YellowScan uses in its Navigator system[6]. This was developed in-house: thus YellowScan is not only an integrator but also a manufacturer.

There's a host of fascinating material in *Photonics Spectra*. The lidar supplier Seyond[7], for example, has partnered with the city of Peachtree Corners, Georgia to create safer streets and smoother traffic flow[8]. Seyond's Falcon K lidar sensors, which operate at 1550 nm and have a maximum range of 500 m, have been deployed at selected intersections. Seyond is a Silicon Valley lidar firm in the automotive space, where it is well established, delivering over 200,000 units in 2023. It also offers Robin W, a shorter-range (905 nm; 150 m), wide field-of-view model.

For many years, the massive potential of the automotive market has motivated lidar suppliers to develop lighter, smaller, less expensive sensors. Our geospatial industry has benefited, because these offer combinations of performance, weight and power consumption ideal for UAV-lidar. We are blessed with imaginative, energetic and talented UAV-lidar integrators, several of which have been featured in *LIDAR Magazine*. They monitor these sensors as they emerge and select candidates for their integrations. It's gratifying to learn, therefore, that vertical-cavity surface-emitting lasers (VCSELs), which we have mentioned in editorials before, are developing apace, targeted primarily at the automotive market. VCSELs have been around for decades, but current advances, mainly beyond my understanding, are dramatic[9]. Interestingly, VCSELs enjoyed a boost in popularity when they were deployed in Apple's iPhone/iPad "Face ID" feature in 2017.

Doubtless many readers receive emails from Markets and Markets, announcing new industry reports. Have you noticed the impressive growth rates that many of these reports announce? There's a recent one on machine vision that predicts a CAGR of 7.3% from 2023 to 2028. Others on AI cameras, 3D printing, 3D cameras, AI sensors, UAVs and hyperspectral imaging give CAGR estimates of 23.9%, 16.4%, 20.3%, 41.6%, 9.9% and 12.6% respectively over similar periods. What does this mean for lidar? Not very much in the direct sense, but there's an underlying message that those technologies which abut our geospatial world are vibrant. We will be able, therefore, to draw on these as building blocks for our purposes. Two reports in areas that already use lidar as one of the enabling technologies, people counting and the automated guided vehicle industry (in applications such as warehouses), give figures of 11.6% and 6.9%. Thanks for reading. Wishing you and yours a bountiful autumn season.

A. Stewart Walker // Managing Editor

3 Abdullah, Q., 2024. Best practices in evaluating geospatial mapping accuracy according to the new ASPRS accuracy standards, *LIDAR Magazine*, 14(2): 37-46, spring 2024

4 Abdullah, Q., 2024. Best practices in evaluating geospatial mapping accuracy according to the new ASPRS accuracy standards, *The American Surveyor*, 21(2): 24-34, May/June 2024.

5 Schrock, G., 2024. The challenger, *xyHt*, 11(6): 30-33, July/August 2024.

6 yellowscan.com/products/navigator-bathymetric-lidar/

7 seyond.com

8 non, 2024. Seyond's lidar solution finds further smart city implementation, *Photonics Spectra*, 58(7): 20, July 2024.

9 Ghods and K. Johnson, 2024. Highly efficient multijunction VCSELs advance for automotive lidar, *Photonics marketplace*, August 2024. photonics.com/Articles/Highly_Efficient_Multijunction_VCSELs_Advance_for/p4/a70100.

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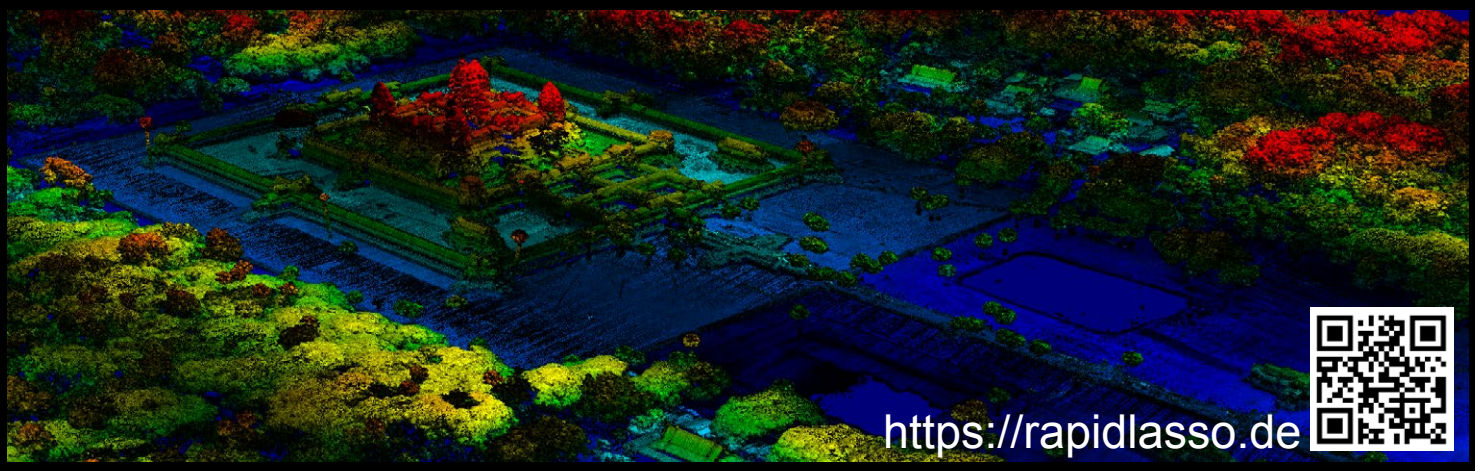


DTM, DSM and orthorectified imagery of Barcelona.

Vexcel Imaging Enters the Lidar Market

Raptors portfolio enhanced by all-Austrian hybrid while popular industry veteran Michael Gruber retires

Recent Vexcel Imaging announcements

Vexcel Imaging, headquartered in the beautiful city of Graz in Austria, is familiar to most readers. Its high-performance aerial cameras, UltraCam Eagle 4.1, UltraCam Osprey 4.1 and UltraCam Condor 4.1, play hard in the global market, supported by UltraMap software. Vexcel Imaging's announcements of sales successes figure prominently on our website. At Intergeo in Berlin in October 2023, however, Vexcel Imaging made two dramatic product announcements. The first was the UltraCam Merlin, based on Bayer-pattern sensors rather than a panchromatic channel to pan-sharpen the RGBN. The second brought Vexcel Imaging vividly into *LIDAR Magazine*'s bailiwick: the UltraCam Dragon is a hybrid, with a VQ-680 OEM 2.4 MHz lidar sensor from RIEGL integrated into the cone.

Vexcel Imaging introduced the Bayer-pattern-based UltraCam Merlin 4.1 (left) and UltraCam Dragon 4.1 (right), its first hybrid aerial mapping system, to the market in October 2023.

BY STEWART WALKER

30 years of excellence: true ortho of Barcelona derived from UltraCam Osprey 4.1 imagery (left); every generation of UltraCam is on display in the museum (right).

In some ways, these developments were natural. Vexcel Imaging is not unknown in the lidar market-place, because its big cameras are often flown in the same aircraft as lidar sensors from Hexagon, RIEGL and Teledyne Geospatial. Vexcel Imaging, however, battles for each camera sale primarily with Hexagon Geosystems, which offers the DMC-4 aerial camera as well as its TerrainMapper-3 lidar; but it emphasizes hybrids in its portfolio - its CountryMapper and CityMapper-2 lines. Furthermore, there are multiple competitors which integrate cameras and lidar units but have lower overheads. The core of all these products is medium-format cameras, typically 150 megapixels. To compete, then, a company must offer attractively priced hybrids. Regardless of the motivation, these developments ensure that Vexcel Imaging has captured readers' attention. Thus we need to learn a bit more about this company's origins and development path. Conveniently, events of a couple of years ago can help us.

Vexcel Imaging provides a wide selection of aerial cameras and hybrid mapping systems designed to meet the needs of all aerial photogrammetry applications.

Visit to Vexcel Imaging in Graz

LIDAR Magazine attended the XXIV ISPRS Congress in Nice in June 2022, then the YellowScan LiDAR from Drone 2022 conference in Montpellier. From there it was possible, en route to visit RIEGL in Horn, Austria, to travel through Graz. Vexcel Imaging has an intriguing history and has been central to advances throughout photogrammetry's digital era. It had just reached its 30th anniversary when managing editor Stewart Walker spent a morning with Chief Scientist Photogrammetry Dr. Michael Gruber to explore the company's history and current directions. To be relevant to the bulk of our readers, however, publication of the interview had to wait for the Dragon to breathe fire!

Views of the UltraScan 5000 film scanner in the museum. The unit was available with either automatic or manual roll-film attachment for scanning rolls of film.

Michael Gruber was waiting for me outside the early 21st century building, in which Vexcel Imaging occupies the first and fourth floors and part of the basement, within easy walking distance of Graz's city center. Vexcel Imaging moved in during 2007. We started in the refurbished foyer and reception area, which serves also as Vexcel Imaging's showroom and museum.

The scanner story

Our discussion began with the UltraScan 5000 scanner, a device to digitize film aerial photography. I knew, however, that earlier scanners, such as the VX2000, VX3000, and VX4000, had come before it. Michael explained: "Vexcel Corporation, founded by Franz Leberl in 1985 in Boulder, Colorado, had successful ventures in ground stations, radar imagery, GIS, and photogrammetry. The scanner division, starting with the VX2000, eventually led to the founding of Vexcel Imaging Corporation, which developed the VX4000 and launched the VX5000 at the ASPRS 2000 conference."

In 1992, Vexcel Imaging GmbH was established in Graz, focusing on scanner development using Kodak's 12,000-pixel linear CCD. Vexcel Imaging Corporation struggled and ultimately closed, however, while the UltraScan was successfully launched by Vexcel Imaging GmbH in 1999.

Michael added: "The initial idea was to market the UltraScan as a graphic-arts scanner, but that didn't work out. So Franz said, 'We'll go for a mapping scanner!' We did, and we've been successful."

Michael paused to reminisce: "I joined Vexcel on February 7, 1993, shortly after its start in June 1992. We began with an empty apartment near the Technical University and had to quickly furnish it to present it as a company for potential funding visitors."

I wondered about the origin of the name "Vexcel" and whether it had a specific meaning. Michael explained, "It's likely a combination of 'vector' and 'pixel,' representing vector data and raster data. It might also incorporate the word 'excellence.' Additionally, Franz comes from a region near the Wechsel mountains in Austria, though with a different spelling."

In 2009, the scanner business was outsourced to Geo Tool Box Ibérica, led by Miguel Pelas. They took over the entire scanner operation, integrating it with their existing software and resources.

The race to a digital aerial camera

In 2000, at the XIXth ISPRS Congress in Amsterdam, the emergence of the Leica ADS40 and Z/I Imaging DMC cameras marked a shift away from fading film camera and scanner technologies. Recognizing the need to adapt, the decision was made to develop an aerial

Michael Gruber, Wolfgang Walcher, Traude Leberl, and Franz Leberl (from left to right) at the ASPRS 2003 Annual Conference during the introduction of the UltraCamD, Vexcel Imaging's first digital aerial camera.

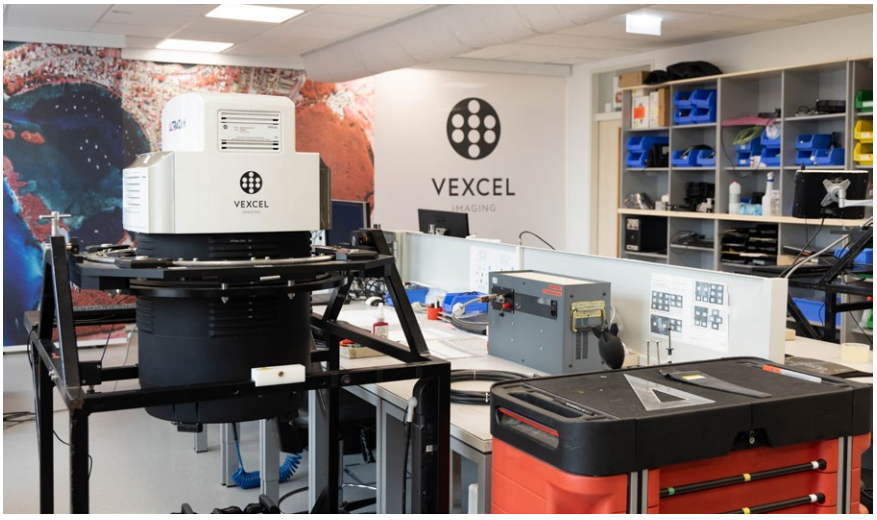
camera as well, which was unveiled at the 2003 ASPRS Annual Conference in Anchorage, Alaska. Early challenges included large storage units and slow data transfer, but the first-generation UltraCam, with its 90-megapixel format, proved successful. This momentum led to the introduction of the UltraCamX in 2006, featuring improved storage and design.

Key to these advancements was the patent on which the cameras are based. Michael Gruber invented the fundamental principle of Syntopic Exposure, revolutionizing the field by enabling the use of true nadir cone arrangements and more efficient sensors that offered higher frame rates and significantly improved image dynamics.

Michael remembered, "The large black and white photo in my office is one of the first UltraCam images, from what I call UltraCamA because it was the first one. It had a manual shutter—I had to operate the shutter string while the pilot gave me a sign based on what he saw on the navigation panel. He did this, and I pulled the string to get the proper overlap—no flight management system at the time."

The mechanics workshop

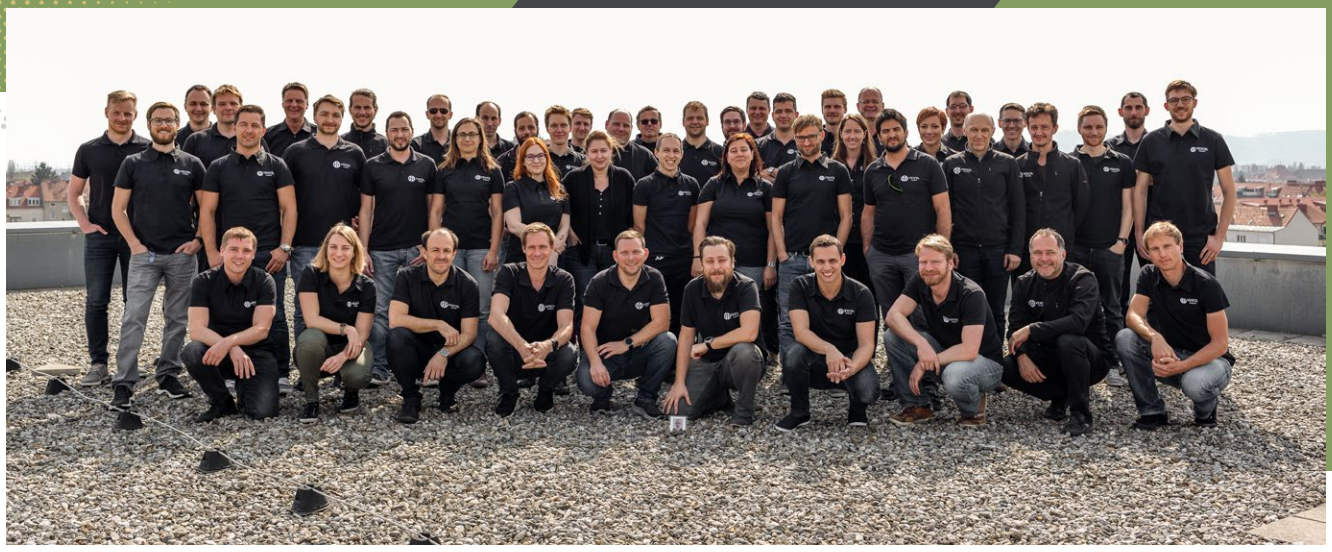
We moved through the building to the rear offices, where I asked Michael about the headcount: approximately 75 in Graz and 10 in Centennial, Colorado. From there, we continued to the mechanics lab and workshop. Michael explained what we were seeing: "Here are our cameras on their special carriages, allowing our support team to handle them easily. When a new camera arrives from Wild Austria, we perform calibration, conduct all necessary tests, complete a final in-house quality control check, and then undertake a flight mission. Every camera undergoes a verification flight where we perform



UltraCam systems are serviced and maintained in the mechanics workshop.

Marc Muick and Michael Gruber (from left to right) working in the office.

A photograph captured by the very first UltraCam hangs on the wall in the office occupied for many years by Michael Gruber.



The highly skilled Vexcel Imaging team at their headquarters in Graz, Austria.

aerial triangulation, assess the camera's quality, and conduct radiometric checks to ensure everything is functioning correctly before it goes to the customer.

"We have a test area in Gleisdorf, a village near Graz, another in the village of Hartberg, and several ground control points in Graz itself. Additionally, we have a test area north of the Alps in case of bad weather."

The second responsibility of this team is support. They handle repairs, servicing, and calibration of UltraCam systems.

Michael continued, "I believe that the variety in our work is why our support staff have an average tenure of over 12 years. Across all departments, we have a very stable team of developers, engineers, and experts with low turnover, which is extremely important. Their deep technical knowledge is central to our success, enabling us to develop faster, innovate more effectively, and respond quickly to market changes."

UltraCam calibration room.

Camera calibration

We moved to the basement, where Vexcel Imaging handles storage and camera calibration. Michael explained that the calibration process begins by precisely measuring fixed points using a total station. The cameras are set up in three specific positions, adjusted for different focal lengths, and then rotated to create a dense grid of control points. This method produces highly redundant images, which are essential for accurately evaluating camera parameters.

Michael noted: "Unlike some methods that use random targets, our approach relies on a limited number of precisely measured positions, ensuring greater accuracy. This method, supported by published papers, can be a strong selling point due to its precision and reliability."

The Microsoft years

During Vexcel Imaging's time as a Microsoft subsidiary, the experience was transformative. Microsoft brought immense value to the company in many aspects such as management, the software development process and innovation, and the company almost doubled its size. In return, Vexcel Imaging was driving significant advancements for Virtual Earth and BING maps. The company also moved to a new building in 2007 that met Microsoft's stringent security requirements.

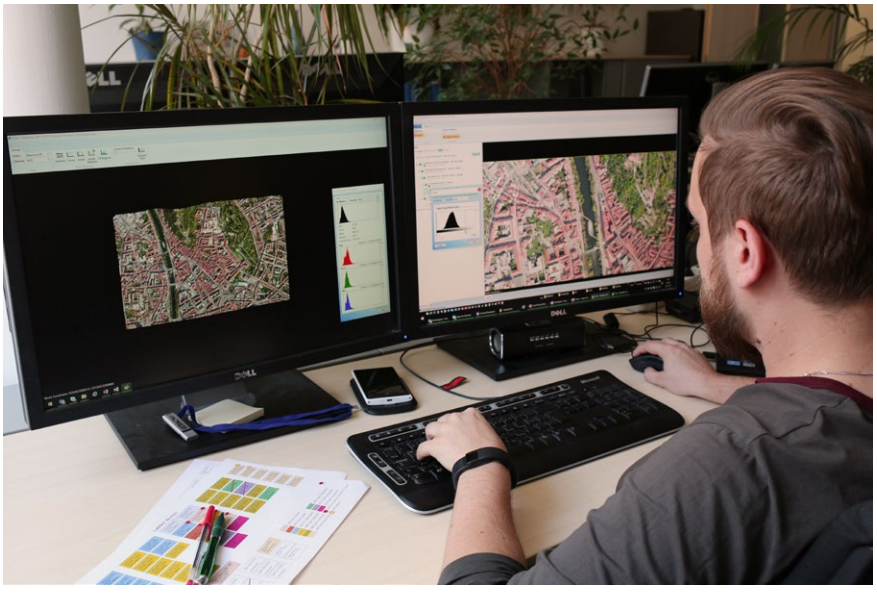
In 2016, ownership of Vexcel Imaging GmbH transitioned from Microsoft to a newly founded holding company in Graz, backed by four key individuals: Erik Jorgensen, former Microsoft Vice President; Stephen Lawler, former BING

A Vexcel Imaging engineer performing a camera calibration.

In 2016, a customer insisted that the mastermind behind the UltraCam sign their new UltraCam Eagle before delivery. Michael was happy to oblige.

CTO; Martin Ponticelli, CTO of Vexcel Imaging; and Alexander Wiechert, CEO of Vexcel Imaging.

When Vexcel Imaging became independent again in 2016, it was remarkable that the company sustained its unique culture, product focus, market, and business rhythm without disruption. Unlike many IT companies that struggle after being acquired by large tech firms, Vexcel Imaging remained intact, continuing to thrive on its own. "For me, it was the second wonder. The first wonder was when Microsoft acquired Vexcel Imaging", Michael elucidated.



UltraMap is Vexcel Imaging's comprehensive all-in-one photogrammetric software suite for processing UltraCam imagery.

The UltraMap software

During our tour of the office, we discussed Vexcel Imaging's software solutions, particularly the UltraMap photogrammetry suite, which includes five modules for processing UltraCam imagery into point clouds, DSMs, DTMs, ortho imagery, and 3D textured TINs. Michael noted that, of the 75 employees in Graz, only 20-25 focus solely on software development, acknowledging that this is a relatively small team. Remarkably, every line of code for UltraCam and UltraMap is developed entirely in-house.

UltraMap was initially designed to process UltraCam image data, from raw files to what are called Level 3. Over time, the team expanded the software to encompass the complete photogrammetric workflow, including aerial triangulation. Initially, they integrated the BINGO software for bundle

UltraCam Eagle Mark 3 ready for data capture. The image format is 26,460 x 17,004 pixels, i.e. 449 megapixels.

adjustment, but later transitioned to the CERES library, embracing new methods from computer vision.

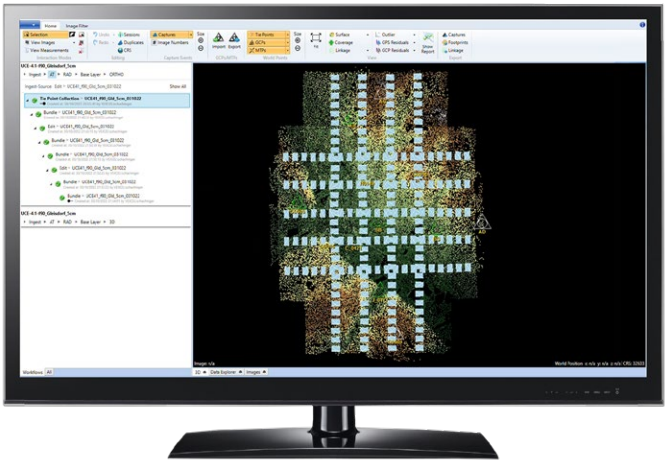
Michael highlighted how Vexcel Imaging benefited from Microsoft's ownership. One of the key developments under Microsoft was dense-matching technology, although they couldn't commercialize it at the time. Michael emphasized that while they couldn't defend the technology in the market, they eventually introduced innovative features such as a visual analyzer in the aerial triangulation module. This tool helps users understand large data blocks, such as identifying different flight days or analyzing tie point collections, enhancing the overall usability and effectiveness of the software.

This user-friendly, highly automated software offers efficient data interaction, editing capabilities, and robust visualizations, complete with integrated quality control tools and options for manual adjustments. UltraMap guarantees successful project execution, no matter the scale or deadline, by providing flexible subscription licensing and distributed processing to maximize performance and scalability.

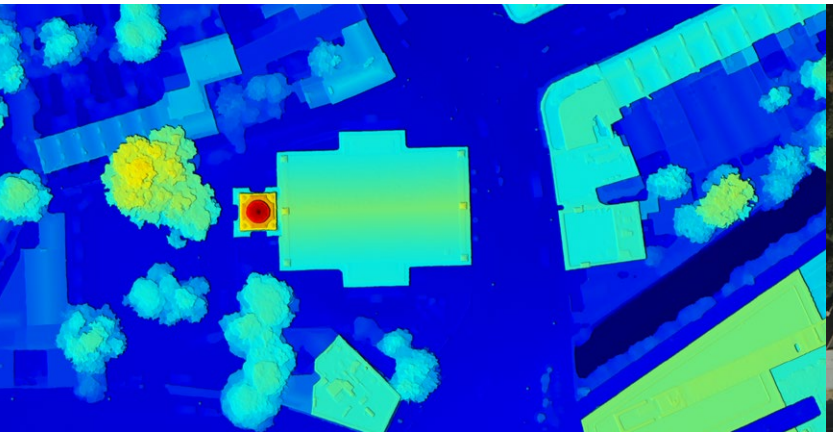
The next generation of UltraCam

Over the years, Vexcel Imaging has achieved significant milestones in aerial camera development, one of which was the introduction of the UltraCam Eagle Mark 3 in 2016. This camera marked a major leap forward, with its pixel count representing a fivefold increase to 449 megapixels per image over 14 years. In 2011, an earlier model of the UltraCam Eagle had become the first aerial camera to capture more than 20,000 pixels across the flight strip.

In 2020, Vexcel Imaging launched the UltraCam Osprey 4.1, the first of its fourth-generation cameras. This model included many innovations, for example, a transition from CCD to CMOS sensors, new sensor electronics, custom lenses, improved motion compensation, and a revamped computer and storage system. The Osprey 4.1 collects nadir and oblique imagery in four directions simultaneously, featuring advanced



UltraMap photogrammetric processing suite.



Views of the same London area: (from left to right) 2.5D DSM and TrueOrtho mosaic (from nadir images); 3D mesh and textured 3D mesh (from both nadir and oblique images).

The UltraCam Osprey 4.1 was introduced in 2020.

panchromatic, RGB, and near-infrared cones. This groundbreaking camera earned Vexcel Imaging a MAPPS Innovation Award.

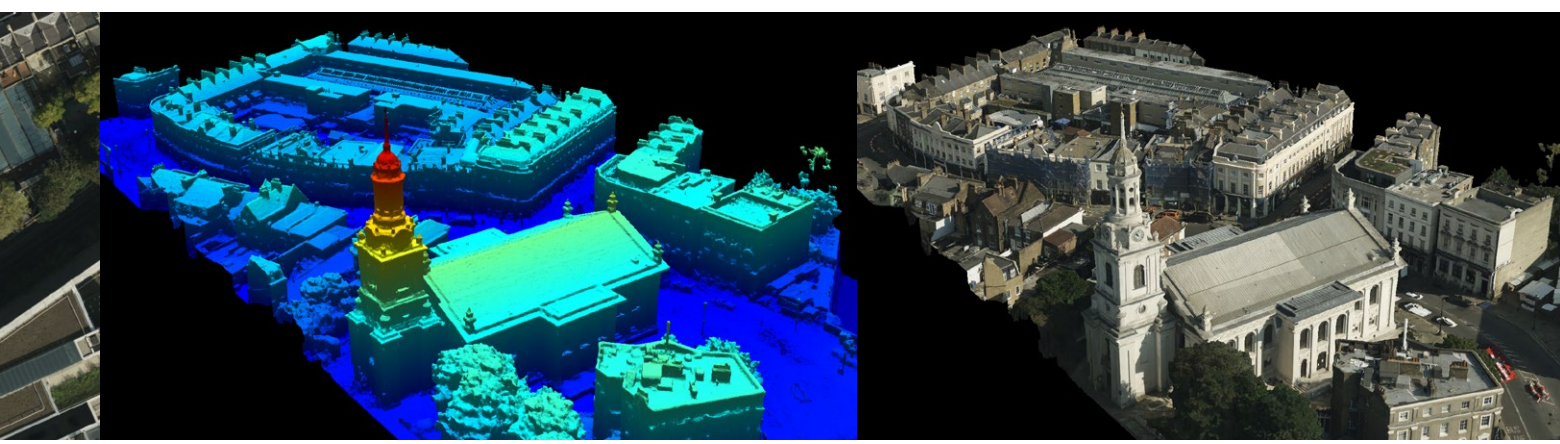
A key advance with the UltraCam Osprey 4.1 was the introduction of Adaptive Motion Compensation (AMC), a novel software-based solution that compensates not only for forward, but also for multi-directional motion blur, making it the only solution of its kind on the market. This technology proved crucial during a 2020 Vexcel Data Program (VDP) mission in London, where the UltraCam Osprey 4.1 successfully captured high-quality imagery at a 3 cm ground sample distance despite challenging conditions, including limited flight windows, cloud cover, and turbulence. The data from this mission remains in the VDP library today.

Given Vexcel Imaging's long-term success and the constant innovations, I wondered what its secret is. Michael gave his opinion: "Besides the excellent team, we have been fortunate to have excellent products at the right time collaborating with the right partners. If you introduce something too early, you must spend a lot until the market is ready. If you're too late, you face strong competitors and miss out on potential market share."

Michael Gruber introduced the transformative UltraCam concept to the market through numerous lectures. Here we see him at the 58th Photogrammetric Week in Stuttgart in 2022.

The Vexcel Data Program (VDP)

In 2020, Vexcel Imaging expanded its long-standing history of remote sensing success by acquiring imagery and aviation assets from Verisk. This acquisition instantly increased the Vexcel Group team to around 450 people.



Aerial imagery and true ortho of Gleisdorf, a small village near Graz, from the UltraCam Merlin 4.1.

Leveraging these new resources, VDP became the provider of the world's largest aerial imagery and geospatial data library, covering over 40 countries. VDP offers eight different products, ranging from oblique to true ortho, DSM to multispectral, and includes Elements for the most up-to-date property and building attributes such as roof condition, roof material, defensible space metrics, and more.

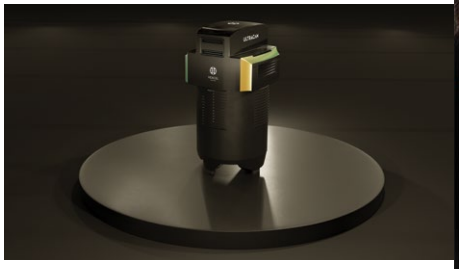
Michael elaborated on this, "A special program within VDP is the disaster imagery service, known as Gray Sky in select countries. Through this program, VDP collects imagery following hurricanes, wildfires, floods, and other disasters, and provides this data to insurance companies, governments, and first responders. We are pioneers in this damage assessment at that scale."

The launch of the fundamental camera family Merlin

In 2023 Vexcel Imaging utilized the simpler technical approach of sensors based purely on Bayer-pattern technology for a new family of cameras called UltraCam Merlin 4.1. Two models, Merlin 2010 and Merlin 3020, have been launched, addressing different

The UltraCam Merlin 4.1 is available in two different configurations.

footprint sizes and budgets. The simpler technical concept of pure Bayer-pattern cameras enables more aggressive pricing in return for some impact on the image quality. Nevertheless, since the Merlins share a great deal with the premium line-up, such as lenses, shutters, camera design and Adaptive Motion Compensation, Vexcel Imaging is carrying the industry-leading UltraCam quality into this camera segment too, as Alexander Wiechert has emphasized on several occasions.



UltraCam Dragon 4.1 hybrid aerial mapping system.

The arrival of lidar: UltraCam Dragon 4.1

As we neared the end of the interview—and remember, this was more than a year before Vexcel Imaging announced the UltraCam Dragon 4.1 with its integrated lidar unit from RIEGL - our conversation moved on to lidar and hybrid sensors. Michael noted that the necessity of lidar would be determined by the market in the coming years, highlighting that Vexcel Imaging's Osprey imagery already supports advanced photogrammetry, especially for urban mapping.

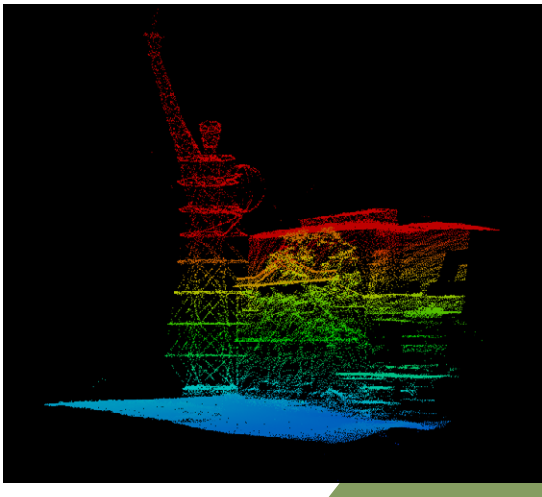
In October 2023, Vexcel Imaging announced its first hybrid aerial mapping system: the UltraCam Dragon 4.1. It produces high-resolution nadir and oblique aerial imagery enriched with precise elevation information from a powerful 2.4 MHz RIEGL OEM lidar scanner. The lidar sensor's innovative multi-axis scanning geometry, including a true nadir scan line as well as forward- and backward-looking scan lines, ensures maximum coverage for truly impressive and complete digital twins. Two high-resolution nadir sensors (RGB Bayer pattern and NIR) and four oblique (RGB) sensors consistently deliver sharp and accurate imagery through advanced image processing techniques, including AMC. Vexcel Imaging's assertion is that the integration of best-in-class sensors facilitates in-depth analysis and a profound understanding of the as-built environment.

Michael Gruber retires

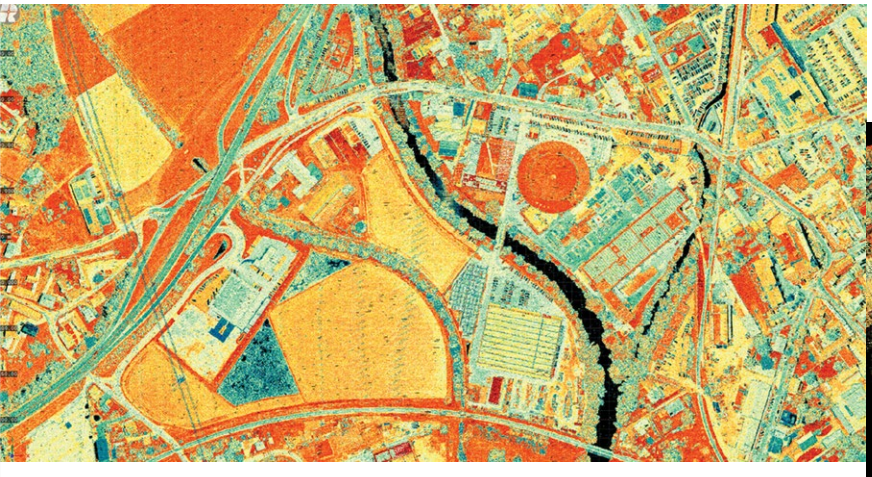
The final incentive to accelerate this piece into print was the announcement in July 2024 that Michael Gruber had retired from Vexcel after more than 31 years with the company. *LIDAR Magazine* congratulates Michael on making an enormous contribution to the aerial mapping business through his work with the cameras over three decades. We hope this article enables readers to remember Michael and value his innovations and energy.

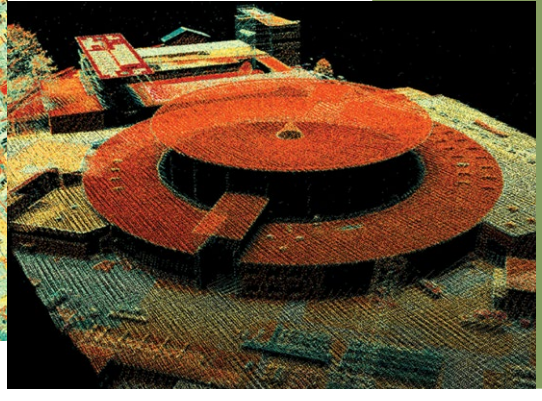
Stewart Walker is the Managing Editor of the magazine. He holds MA, MScE and PhD degrees in geography and geomatics from the universities of Glasgow, New Brunswick and Bristol, and an MBA from Heriot-Watt. He is an ASPRS-certified photogrammetrist.

Michael Gruber and Alexander Wiechert, CEO of Vexcel Imaging (from left to right), on the occasion of Michael's retirement.



Lidar data captured in Graz, Austria, with the UltraCam Dragon 4.1.





Lidar data from Gleisdorf, captured with the UltraCam Dragon 4.1 during a test flight.

SBG SYSTEMS

APPLICATIONS

- AIRBORME
- AUTOMOTIVE
- DEFENSE
- INERTIAL
- MAPPING
- MARINE
- SURVEYING
- UNMANNED

COMPANY PROFILE

SBG Systems is a fast-growing supplier of miniature, high-performance, and innovative motion sensing solutions. SBG Systems is headquartered in Carrières-sur-Seine, France, and operates in North America from its subsidiary in Santa Anna, CA, and in Asia with its subsidiary in Singapore.

SBG Systems offers a complete line of inertial sensors, such as Attitude and Heading Reference System (AHRS), Inertial Measurement Unit (IMU), and Inertial Navigation Systems (INS), based on the state-of-the-art MEMS technology. This technology combined with advanced calibration techniques offers miniature and low-cost solutions while maintaining a very high performance at every level. Our sensors are ideal for projects such as unmanned vehicle control, antenna tracking, camera stabilization, and all surveying applications. From hydrography to mobile mapping and aerial cartography, SBG Systems offers a complete solution including the IMU, PPK software, and services.

SBG SYSTEMS

Founded 2007
11–50 Employees
Carrières-sur-Seine, France
Santa Ana, CA

sbg-systems.com

SBG Systems Unveils Quanta Plus

The Next-Gen OEM GNSS-Aided INS

SBG Systems, a leading provider of navigation technology, is thrilled to present Quanta Plus, its latest Inertial Navigation System (INS). Quanta Plus is a small, lightweight, and high-performance OEM product that can be easily integrated into survey systems with LiDAR or other third-party sensors.

Quanta Plus: Optimized SWaP and Stellar Performance in Harsh Environments

Quanta Plus is engineered to deliver accurate and reliable navigation data even in the most demanding environments. It combines a high-performance miniature tactical IMU with a GNSS receiver that is resilient to harsh covering conditions, providing RTK fixes even in challenging situations (0.015° roll/pitch, 0.04° heading, 1cm positioning in RTK).

The system boasts a wide range of features to make it easy to use and customize for various applications and features a built-in datalogger, ethernet interface for seamless integration, and a user-friendly web configuration UI for simple setup and control.

Quanta Plus is a must-have device for any survey professional or navigation-dependent company looking for a high-performance and robust navigation solution. With its cutting-edge technology, outstanding SWaP-C, and ease of use, Quanta Plus is set to become the new industry standard.

Quanta Plus also benefits from easy integration within Qinertia, SBG Systems' state-of-the-art post-processing software.

Qinertia 4: Post-Processing Made Easy for all Surveyors' Projects

SBG Systems' Post-Processing software called Qinertia gives access to offline RTK corrections from more than 10,000 base stations located in 164 countries. Trajectory and orientation are then greatly improved by processing inertial data and raw GNSS observables in forward and backward directions.

Qinertia 4 is packed with many innovative features, such as the extended CORS network support and Ionoshield PPK mode, for example.

SBG SYSTEMS

High-Performance INS Solutions for Surveying Applications

NEW QUANTA SERIES

- Designed for Seamless OEM Integration
- Robust to Vibrating Environments
- Post-processing with Qinertia PPK Software

Quanta Micro

Quanta Plus

Quanta Extra

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Stonex USA

COMPANY PROFILE

STONEX is one of the world's leading companies in the production of measuring and survey instruments, with over 200 qualified distributors worldwide. The company places the maximum attention on innovation and development of solutions for surveying, precision positioning, GPS networks, and 3D Scanning. The company aims to offer a portfolio of services and products of high quality that meets every need both during the purchase phase and after-sales.

Stonex produces high-quality survey instruments and sells them all over the world thanks to its partners.

The products offered by STONEX include:

- Total Stations
- High precision GNSS receivers
- Handheld GPS/GNSS solutions for GIS and Mapping
- CORS networks systems
- Rugged instruments for the construction sector
- Laser Scanners
- GIS, Topography and 3D scanning Software
- Precision Farming solutions
- Machine Control solutions

STONEX U.S.A.

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+39 02 78619201
info@stonex.it

stonex.it

APPLICATIONS

- SURVEYING
- MAPPING
- GNSS NETWORKS
- GIS
- 3D SCANNING
- MONITORING
- PRECISION FARMING
- MACHINE CONTROL

Stonex Laser Scanners are the perfect companions for your field surveys

Compact, Easy, Reliable

Stonex laser scanners are precise and easy-to-use instruments, collecting detailed point clouds will not be a problem.

The new X70^{GO} SLAM is a real-time 3D model reconstruction device which integrates inertial navigation module, high performance computer and storage system. It is equipped with a 360° rotating head, which, combined with the SLAM algorithm, generates high-precision point cloud data. X70^{GO} merges mobile and stationary surveying thanks to the X-Whizz function. To the advantageous SLAM solution that allows you to to collect data on the move in a very short time, it combines a stationary mode to scan with higher resolution.

X120^{GO} SLAM laser scanner has a 360° rotating head, which can generate a 360°x270° point cloud coverage and it is equipped with three 5MP cameras to generate a 200°FOV horizontal and 100°FOV vertical. If you need a SLAM laser scanner to survey large areas, maybe with a vehicle, the X120^{GO} is the tool for you.

The XVS vSLAM Scanner is something unique on the market! This handheld scanner uses a technology based on the integration of high-resolution images, inertial systems and a complex algorithm: capturing a scenario with XVS, 3D model will be generated through photogrammetric techniques. Easy like a phone, powerful like a scanner.

X100 is a compact and lightweight tripod scanner that allows you to scan indoors and outdoors quickly, and thanks to the integrated panoramic camera you will obtain coloured point clouds.

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GEOCUE

COMPANY PROFILE

GeoCue is the largest supplier of kinematic lidar processing tools in North America and LP360 is one of the world's most widely used tool for exploiting point cloud data. In 2022, GeoCue and Microdrones joined together to bring geospatial experts the very best in drone surveying equipment, geospatial software, workflow, training and support for high accuracy LiDAR and drone mapping to help civil engineering and surveying professionals achieve successful data collection, processing, and management.

With TrueView drone LiDAR/Imaging sensors, LP360 point cloud data processing software, and fully integrated systems from Microdrones, we are the leader in LiDAR mapping processing in North America able to meet customers where they are in terms of technology adoption, budget, and resources.

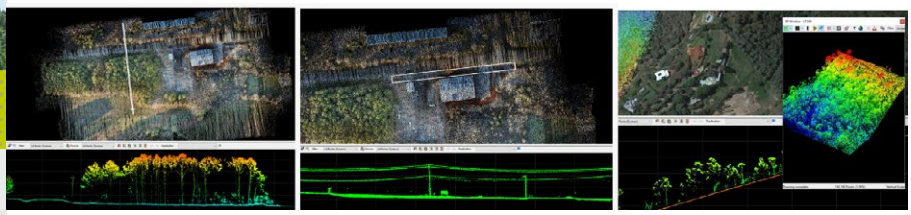
GEOCUE

Founded 2003
11-50 Employees
520 6th Street Madison, AL 35756

geocue.com

APPLICATIONS

- MAPPING
- PROCESSING
- SURVEYING
- UNMANNED
- AERIAL
- CONSULTING



The Leaders in LiDAR Mapping Hardware & Software Since 2003

Powerful LIDAR + Dual Camera Sensor integrations, post processing software and data management for high accuracy drone mapping applications.

Fly, Process, Deliver—All in One Solution

GeoCue's True View 3D Imaging Sensors offer an innovative drone mapping solution supporting LIDAR, photogrammetry, and direction geo-referencing solutions integrated in lightweight payloads. GeoCue focuses on offering full solutions rather than individual parts. Unlike other drone LIDAR providers, GeoCue includes post-processing software and a data management portal to provide users with a complete solution from flight to post-processing and data delivery.

Utility-Grade to Survey-Grade 3D Imaging

GeoCue offers a series of True View 3DIS systems ranging from utility grade to survey grade ensuring successful drone mapping projects no matter the application. The True View 3DIS includes all the components and software necessary to collect LIDAR and RGB image data and process these data to a 3D colorized point cloud in LAS format. True View systems use Applanix POS for best-in-class position and orientation accuracy.

LP360 LiDAR & Photogrammetry 3D Point Cloud software

Whether it's airborne or terrestrial collected LIDAR data, 3D point clouds have become a critical element in mapping. LP360, an advanced desktop LIDAR software package, makes easy work of extracting information and generating deliverables in an intuitive GIS environment. Now, with an ever-growing collection of cloud-based tools and resources that will make it easy for you to manage, archive, share and collaborate on geospatial projects.

LP360 DRONE

Wingtra LIDAR is now supported by LP360!

The latest updates in LP360 can take your data to the next level.

Are you using the new Wingtra LIDAR Solution to capture 3D data for large aerial surveying projects? Then take that data to the next level with LP360 Drone LiDAR & photogrammetry 3D point cloud software.

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The fully integrated workflow of LP360 Drone lets you Fly, Optimize and Deliver fully processed data into actionable results. Learn how you can get the most out of your Wingtra LiDAR with LP360 Drone.

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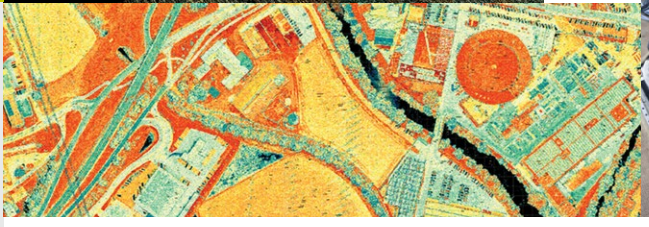
LP360 Cloud is an ever-growing collection of cloud-based tools and resources that will make it easy for you to manage, archive, share and collaborate on geospatial projects.

- Store and manage data
- Stream pointclouds
- Discover Powersearch to localize all available datasets within a geographical area

Vexcel Imaging

APPLICATIONS

- AIRBORNE
- SURVEYING
- CARTOGRAPHY
- PHOTOGRAMMETRY
- LIDAR



COMPANY PROFILE

When you combine expertise in aerial cameras, hybrid mapping systems, and photogrammetry software with the largest aerial imagery and geospatial data program in the world, you get the industry leaders in aerial imaging.

VEXCEL IMAGING develops the world's most widely adopted aerial systems and photogrammetric processing software with constant product upgrades and world-class support. The broad UltraCam lineup offers optimized systems for all applications in airborne photogrammetry. The sophisticated UltraMap software Suite provides an end-to-end workflow for highly automated generation of quality data products including point clouds, digital surface and terrain models, orthophotos and 3DTINs.

The VEXCEL DATA PROGRAM (VDP) features the world's most comprehensive and accurate off-the-shelf library of aerial content in 35+ countries. VDP offers 8 different products including Elements for most up-to-date property and building attributes.

VEXCEL IMAGING

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The Ultimate Hybrid Aerial Mapping System

The UltraCam Dragon 4.1 is Vexcel's first hybrid aerial mapping system, offering deep insights into complex environments at the highest collection rate. The UltraCam Dragon 4.1 maximizes productivity, accuracy, and target coverage. The system produces high-resolution nadir and oblique aerial imagery, enriched with precise elevation information, obtained by a high-performance 2.4 MHz RIEGL Waveform LiDAR scanner, collecting up to 2 million measurements per second.

With a choice of two focal lengths, the system excels in challenging environments and broadens its application scope, compared to pure imaging sensors. This advantage is particularly evident in tropical urban areas, where the LiDAR's multi-target capability enables the detection of 3D ground points beneath dense vegetation. In densely populated cities with tall buildings, where photogrammetric methods struggle with obstructed lines of sight, the LiDAR's unique scanning pattern proves invaluable. The LiDAR provides forward, nadir, and backward scan lines at angles of +20, +10, 0, -10, and -20 degrees in the flight direction. This configuration is crucial for penetrating both the steepest building canyons and the interior courtyards with the nadir scan line, and for additionally measuring building facades.

The result is an information-rich point cloud that enhances derivative products like Digital Surface Models (DSM), Digital Terrain Models (DTM), and 3D Triangulated Irregular Networks (TINs). By enriching the traditional aerial view with multi-dimensional data layers, the UltraCam Dragon 4.1 enables a more comprehensive analysis and understanding of any environment.

VEXCEL
IMAGING

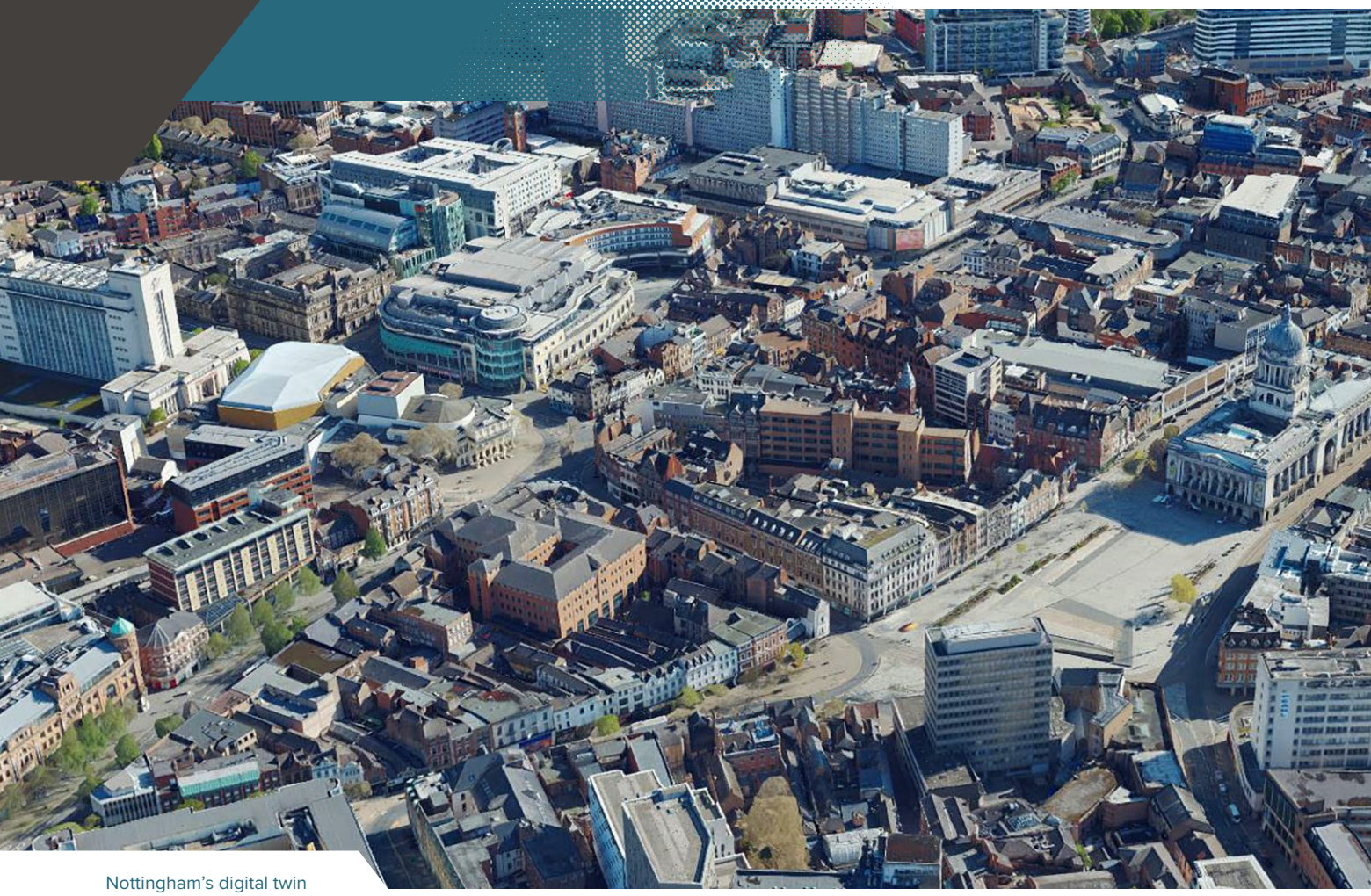
DRAGON

Expand your perception

ULTRACAM

RIEGL inside

See why our brand-new UltraCam Dragon 4.1 is the perfect fit for your complex environment mapping projects.



Nottingham's digital twin

A Digital Twin for Nottingham

Harnessing the power of hybrid sensors to optimise urban planning

As urban environments continue to evolve, local authorities require increasingly comprehensive and accurate geospatial data to inform governance, planning, and communication with their communities. Smart city initiatives are making this happen by harnessing the power of reality capture to generate digital twins of entire cities.

One example is the city of Nottingham in the UK. With increasing national demand to see cities in 3D and digitize planning processes, Nottingham City Council set out to develop a digital twin of the city.

BY ADINA **GILLESPIE** AND LAYTON **HOBBS**

Leica CityMapper-2 hybrid airborne sensor

Using data captured from hybrid airborne sensors to create a 3D model, they were able to transform their decision-making processes, optimize urban planning for more sustainable city growth, and establish a blueprint for other local authorities looking to develop their own urban digital twins.

A digital twin would allow the council to streamline its approach across departments, as new developments could be planned, presented, and shared in an immersive real-world environment with all the relevant data available. They also wanted the digital twin to be widely accessible to boost public engagement, for example when considering the effects of new developments on the environment.

> "Local authorities require increasingly comprehensive and accurate geospatial data to inform governance, planning, and communication with their communities."

Nottingham City Council recruited the expertise of Bluesky International, an aerial survey company that deploys Leica Geosystems' airborne solutions. Through this partnership, the council has developed a digital twin of the entire city—establishing Nottingham as a pioneer in digitally advanced city planning.

Mapping Nottingham from the sky

The first stage in creating a digital twin of a city is an aerial survey. The Leica CityMapper-2[1] urban mapping sensor was chosen for its ability to capture imagery and lidar simultaneously. This hybrid system enabled Bluesky International to create an accurate and detailed 3D model of Nottingham by capturing vertical and oblique imagery together with high point density (30 ppsm) lidar.

Using the data captured with Leica Geosystems' technology, Bluesky International could generate highly detailed orthophotos, point clouds, 3D building models, and meshes with <5 cm resolution, all from a single flight. This contributed to reduce the total flying costs and carbon emissions while

1 leica-geosystems.com/products/airborne-systems/hybrid-sensors/leica-citymapper-2

Nottingham's digital twin makes decision-making processes more transparent, optimising urban planning for more sustainable city growth and innovation

creating data adaptable for a wide range of applications.

"In one flight we can capture all the required data," says Ralph Coleman, Chief Commercial Officer at Bluesky International. "This makes us cost-effective for our customers while also helping us meet our ambition to achieve carbon neutrality."

Furthermore, all these benefits come without customers having to sacrifice on quality. "On the contrary," says Coleman, "we can deliver datasets that meet our customers' demands on both accuracy and quality."

A total of 7.5 TB of data was captured, including 13,885 images. This level of data gives Nottingham's digital twin unparalleled accuracy and depth, so city managers can shape their urban landscape with the utmost precision.

From 2D to 3D

The shift to 3D geospatial data makes urban planning more efficient and highlights new opportunities. It enables more detailed insight into digital simulations of urban scenarios, from transport improvements to new construction.

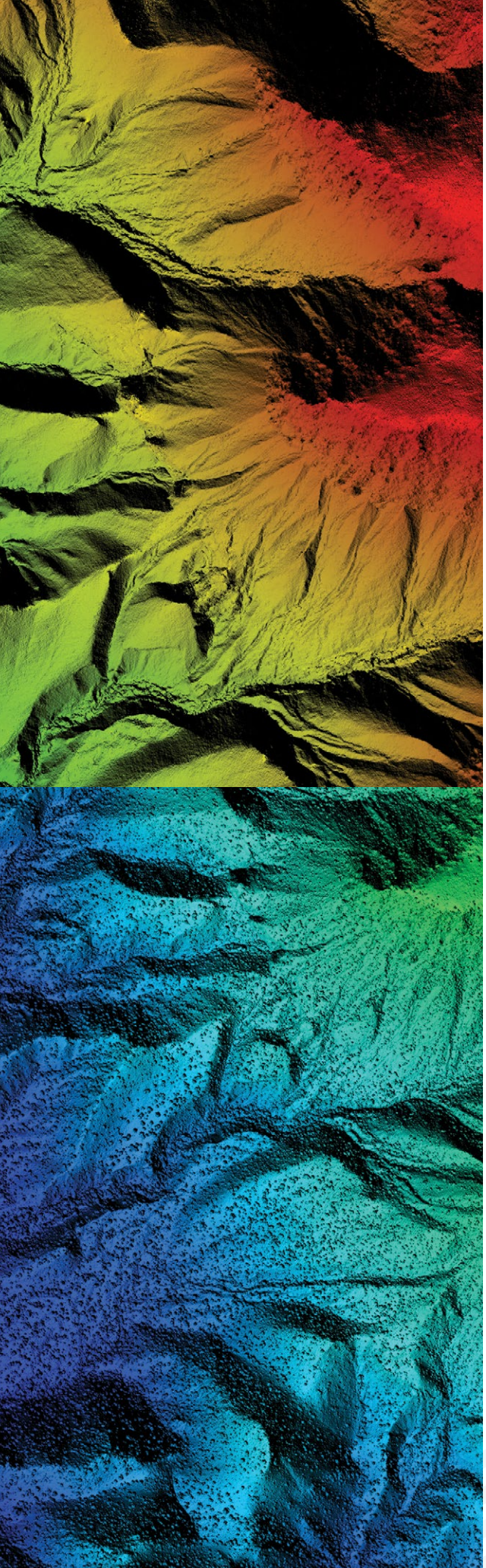
Bluesky International seamlessly processed both imagery and lidar data within the same environment using the high-performance processing workflow software HxMap[2], which supports Leica Geosystems' airborne sensors. This allows for the generation of highly consistent data products crucial for creating Nottingham's digital twin.

Increased transparency

A key goal for Nottingham City Council was to ensure access to digital-twin data across all the departments. The transition from 2D to 3D data has unlocked a new dimension of clarity and insight: by integrating the 3D mesh, the council could offer unparalleled visual fidelity and depth.

The digital twin now means planners can share their proposed developments by dropping 3D building models into the digital twin. Each can then be linked to relevant documents within the digital twin, for example, planning permissions

2 leica-geosystems.com/en-gb/products/airborne-systems/software/leica-hxmap



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and proposals. Planners can then carry out site and morphology assessments of any new development using tools like line of sight, shadow assessment, and measurement embedded in the digital twin. This way they can more quickly assess the potential impact any new development will have on the surrounding area.

For Nottingham's urban planners, 3D models are now established as a fundamental part of their assessment of major applications. With the digital twin, they can undertake constraints checks, accessibility analysis, and better understand the available infrastructure and amenities nearby. This way, the digital twin has increased the speed of decision-making and boosted confidence that developments will suit the environment.

Besides streamlining and enhancing the planning process, the creation of an easy-to-access digital twin helps foster public engagement, transparency, and more efficient public spending. "Ultimately, the beneficiaries of this data are the citizens," says Coleman.

Future applications

The Nottingham City Council team is now working on combining aerial data captured with the Leica CityMapper-2 with data captured from mobile mapping technologies. This means new developments will be presented in an immersive real-world environment, increasing the scope of possible use cases for the data.

For critical infrastructure, planning can all take place within this immersive environment. Everything is streamlined, from highway scheme planning, asset capture, and network assessments to planning public safety measures, such as flood risk assessments or identifying the best CCTV placement positions on buildings. Similarly, this environment will enable more sustainable city development, including the effective planning of green spaces and examining potential areas to install renewable energy facilities, such as solar panels.

> "A more immersive, photorealistic digital twin is also more accessible to people not used to interpreting 3D models, such as planning committees and the public."

A more immersive, photorealistic digital twin is also more accessible to people not used to interpreting 3D models, such as planning committees and the public. This enables the council to share development plans more widely with residents in a format which is easier to understand.

As Laura Pullen, GIS Business Development Manager at Nottingham City Council, explains: "We hope to build on the work to date and, as we move forward, start to create hybrid mesh models incorporating street level photo capture for applications with transport planning and biodiversity studies, for example."

"Working with a digital twin at this scale is not without its challenges, though," said Pullen. "New skills have to be identified to make the best use of the new technology and data becomes critical in terms of its quality and timeliness."

Nottingham City Council is at the forefront of revolutionizing urban planning practices, setting a precedent for local authorities across the UK. The council's ultimate aim is to establish a blueprint for other local UK authorities looking to develop their own urban digital twins. This is because 60% of UK planning authorities are using the same GIS technology as Nottingham City Council. Nottingham's new digital twin, therefore, shows others how this technology can be deployed to reshape their own urban environments.

By embracing digital twin technology, the council is not only streamlining planning processes but also fostering greater transparency, engagement, and efficiency in shaping the future of its cityscape.

Adina Gillespie is Vice President of Strategic Initiatives at Hexagon's Geosystems division. With over 15 years of experience in earth observation technology, she focuses on advancing the adoption of technology and data analytics in institutions. Her primary goal is to optimize the utilization of remote sensing technology in both the public and private sectors.

Layton Hobbs is the Product Line Director for Airborne Solutions at Hexagon's Geosystems division, where he and his team are responsible for topographic lidar, aerial camera systems, and related software solutions. Layton applies decades of lidar and imaging experience to the development of Leica Geosystems' sensor roadmap, leads new product strategy, and works to build awareness and understanding in the industry.

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NV5

COMPANY PROFILE

NV5 provides engineering, technology, and consulting services for both public and private sectors. We are the world's leading provider of comprehensive geospatial software and services. With over 1300 dedicated geospatial professionals who use our solutions to acquire, analyze, and answer to answer their most challenging questions.

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- We build and deploy enterprise GIS environments and use DevSecOps best practices to build, deploy, and support applications.
- We integrate real-time information and perform analytics to assist our customers in making decisions.
- We provide staff augmentation by placing our staff into a customer footprint to meet mission requirements.
- We build, deploy, and support software products that help clients worldwide manage and analyze geospatial data to meet their needs.
- We work with customers across the globe and have completed projects on all 7 continents and in over 182 countries.

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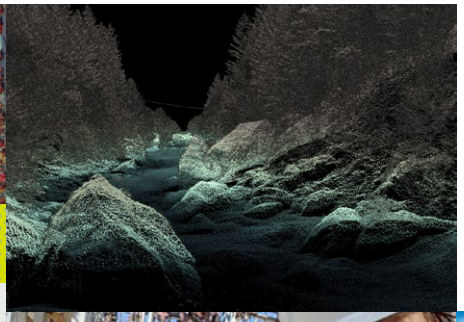
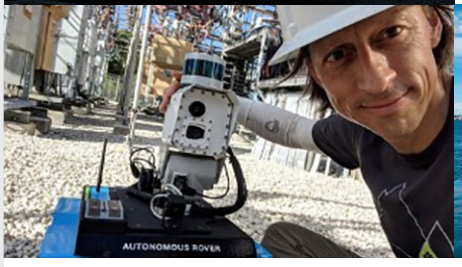
APPLICATIONS

- SURVEYING AND MAPPING
- DIGITAL TWIN
- DATA & IMAGE PROCESSING
- ANALYTICS
- SOFTWARE & BUSINESS SOLUTIONS
- ENTERPRISE GIS & CLOUD
- FACILITY & SYSTEM SECURITY

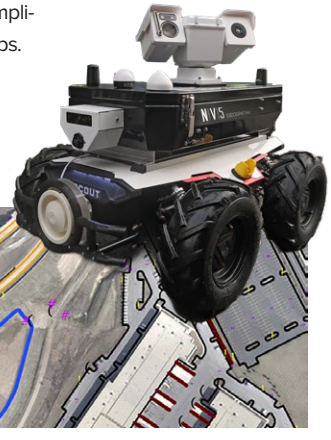




End-to-end Geospatial Solutions

NV5 drives change in acquiring, producing, and applying high-resolution, high-accurate datasets. We transform these dense unstructured data into structured datasets optimized for our geospatial scientists, industry experts, GIS developers, and software engineers to create data analytics and software applications uniquely designed to meet our client's needs. Our R&D investment in next-gen solutions keeps us at the forefront of the market.

Our geospatial services have strategic value in countless applications, from habitat assessment and land use planning to regulatory compliance, engineering design, disaster preparedness, and DevSecOps. We've successfully delivered well over one million square miles of geospatial data to support projects for federal, state, tribal, private, and non-governmental organizations.



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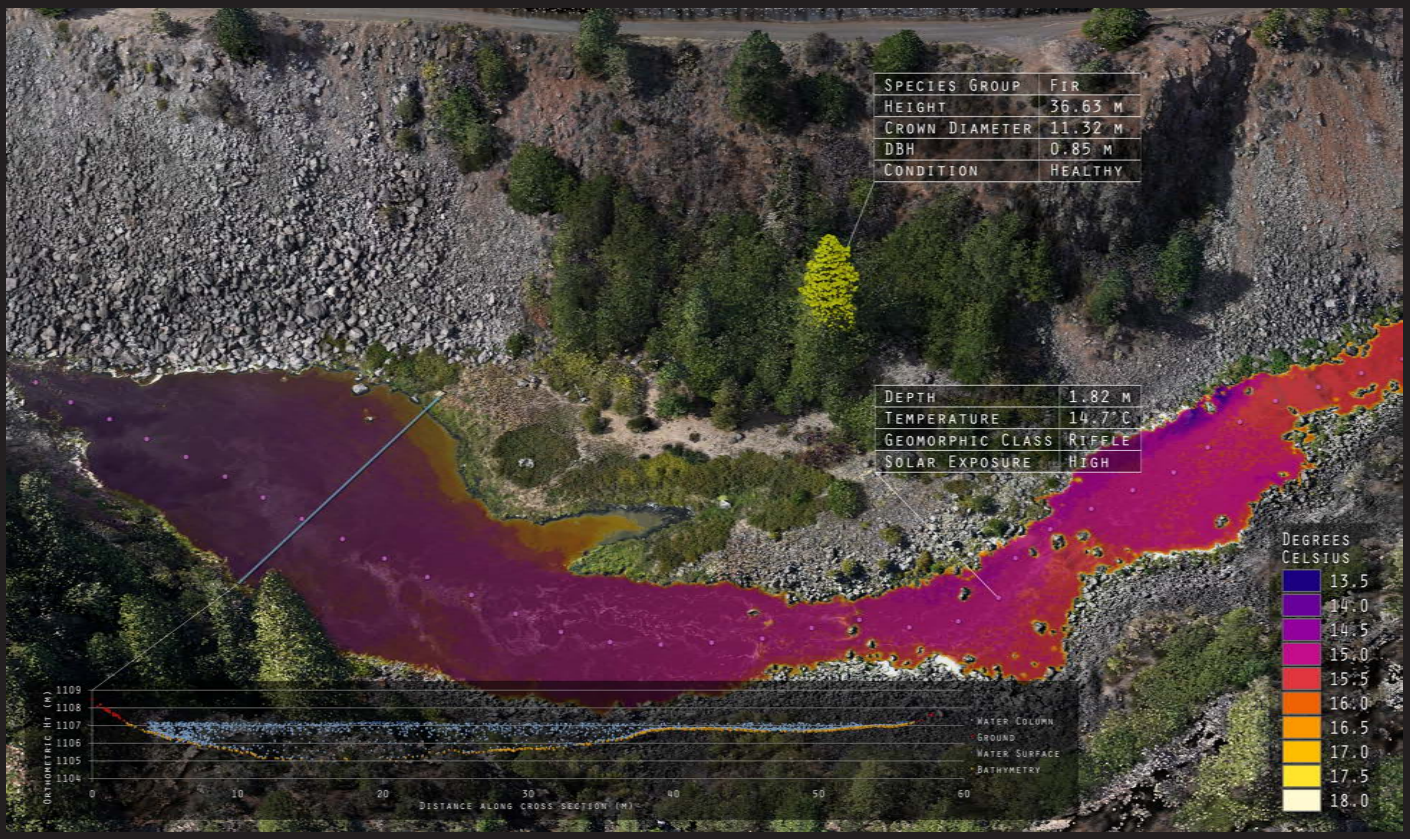

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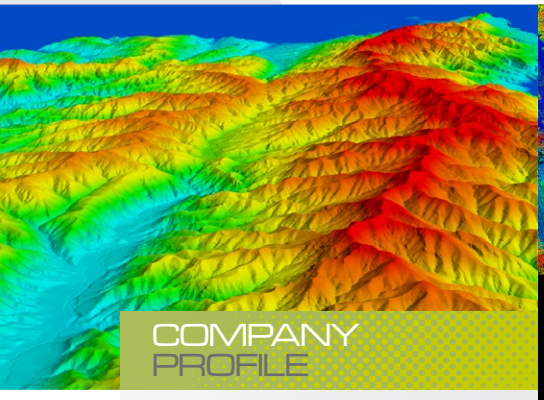

COMPANY PROFILE

Dewberry is a leading, market-facing firm with a proven history of providing professional services to public- and private-sector clients. Established in 1956 and headquartered in Fairfax, Virginia, our professionals are dedicated to solving clients' most complex challenges and transforming their communities. The firm harnesses the power of geospatial science to offer complete end-to-end remote sensing and mapping services starting with state-of-the-art airborne lidar sensors to automated processing, surveying, web/mobile GIS, and advanced data analytics. Dewberry creates, analyzes, and builds geospatial data and tools, to help clients integrate, share, and simplify the use of information allowing for more effective and efficient decision making. To learn more, visit www.dewberry.com.

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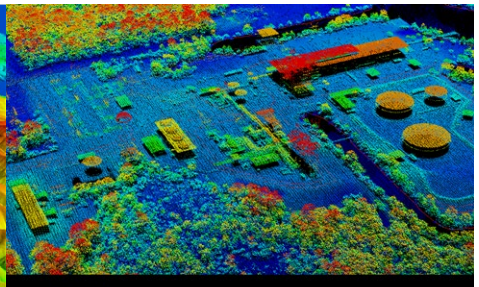
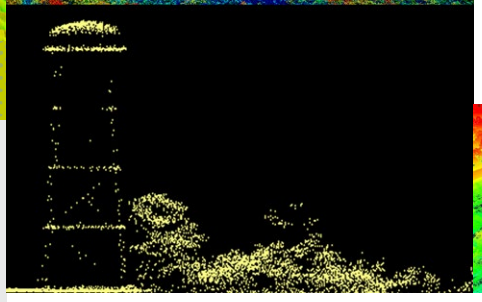
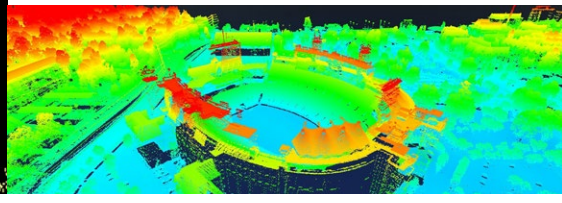




APPLICATIONS

- REMOTE SENSING
- TOPOGRAPHIC LIDAR
- TOPOBATHYMETRIC LIDAR
- GIS
- APPLICATION DEVELOPMENT
- MODELING
- ASSET MANAGEMENT
- ANALYTICS



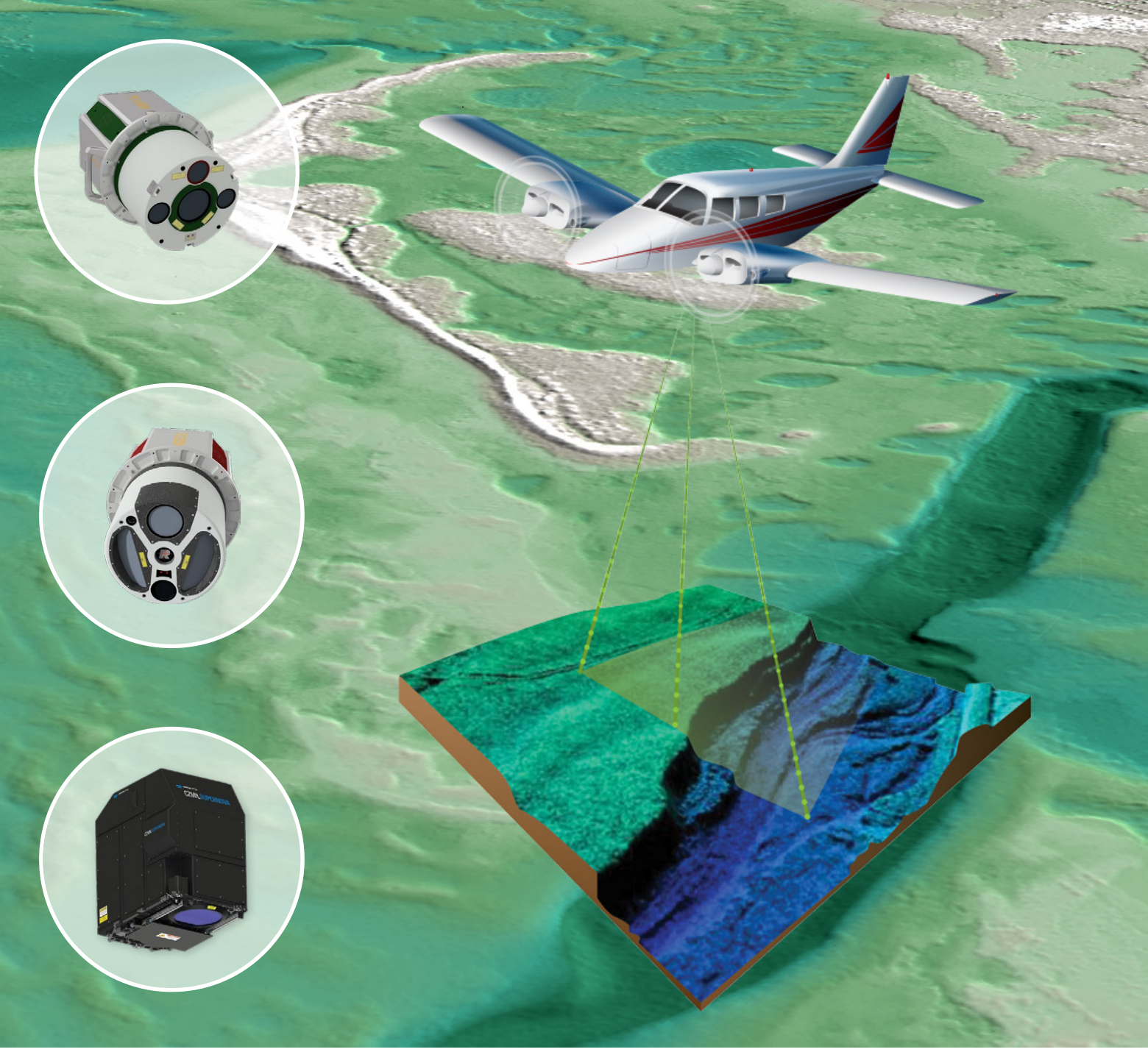
Dewberry's Geospatial and Technology Services

Dewberry's geospatial and technology services team creates, analyzes, and builds tools to share geospatial data, and helps clients integrate these tools into their daily lives. By fusing multiple data sets together, Dewberry provides clients with easy-to-use tools that simplify the use of information to allow for more effective and efficient decision making.

Dewberry recently purchased three sensors—the RIEGL VQ-1560 IIS topographic airborne lidar sensor and two topobathymetric lidar sensors—RIEGL VQ-880-G-II and the CZMIL SuperNova. This investment allows Dewberry to expand its mapping capabilities with current clients, keep the entire acquisition lifecycle in-house, and monitor the quality of its products. The firm is excited to empower their clients with access to the most innovative technology to meet their topographic/lidar needs, delivering hi-definition lidar datasets quickly and efficiently.

The firm's solid performance processes in geospatial technologies and corporate IT services led to it being appraised at Level 3 of the CMMI Institute's Capability Maturity Model Integration (CMMI) in Services and Development Models. In 2022, Dewberry also received the MAPPS Geospatial Excellence Award for GIS/IT/Remote Sensing Analysis and the Esri Systems Integrator Award for Innovation.

Dewberry works seamlessly to provide geospatial mapping and technology services across various market segments. With more than 30 years' experience, the firm is dedicated to understanding and applying the latest tools, trends, and technologies. Dewberry employs the latest GIS software and database platforms, including the full suite of ESRI products. The firm's products and services include application, web, and cloud-based development; system integration; database design mapping; data fusion; and mobile solutions.



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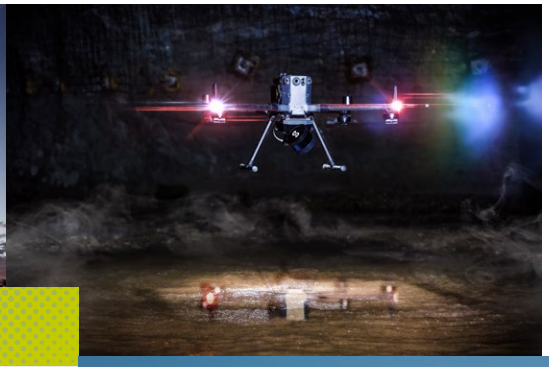

APPLICATIONS

- SURVEY
- MGIS
- UNMANNED
- SCANNING
- MONITORING
- PRECISION AG
- BUILD & CIVIL CONSTRUCTION

COMPANY PROFILE

Frontier Precision's measure of excellence can be traced to 1988. We've been at the forefront of technology, continually offering customers new tools and solutions, all with our end goal of making our customers more efficient, productive, and profitable with today and tomorrow's technology. Frontier Precision is an employee-owned company—offering solutions in Survey, Mapping & GIS, Drones/UAS/Unmanned, Build Construction, Civil Construction, Scanning/Imaging, Mosquito & Vector Control, Precision Ag, Water Resources, and Invasive Plant Control. We became one of Trimble's largest geospatial dealers worldwide by offering our customers the solutions they need. Every day, we bring it to life by seamlessly connecting our physical and digital worlds to use technology to improve how we interact better with the earth—in all kinds of meaningful ways.

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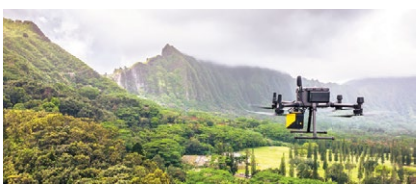

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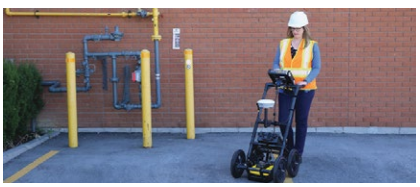

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We have a large user base and an exceptional rate of customer retention over our 41-year history, and we are the only company to provide free tech support since the day of our founding.

Our wide product range includes Carlson PhotoCapture for photogrammetry and UAV mapping, Carlson Precision3D for engineering design in 3D, and solutions that include SurvPC data collection software, data collectors, GNSS receivers, robotic total stations, and laser scanners.

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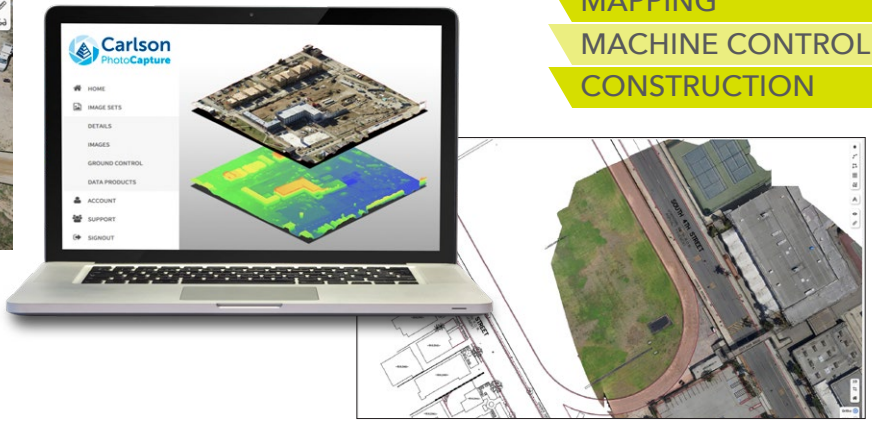
APPLICATIONS

- (LAND) SURVEYING
- MINING
- (CIVIL) ENGINEERING
- GIS
- MAPPING
- MACHINE CONTROL
- CONSTRUCTION



Integrated Photogrammetry + LiDAR Solutions

Carlson's photogrammetry solutions take you from flight planning, through image processing, to point clouds, to surfaces, elevation models, and CAD deliverables.

Carlson's solutions for photogrammetry and LiDAR range from sUAS solutions with LiDAR and photogrammetry capabilities to Carlson PhotoCapture, which provides powerful, versatile, scalable photogrammetry processing with LiDAR integration, to Carlson Point Cloud, which enables powerful point cloud manipulation and provides output to CAD Carlson PhotoCapture is available in two versions:

Carlson PhotoCapture Online may be used on any device with access to the internet. All that's required is a yearly membership and the purchase of processing capacity as needed. No minimum monthly fees, and projects may be shared for collaboration with coworkers and clients.

Carlson PhotoCapture Standalone is for customers who need Carlson's photogrammetry solution but want to process locally. Now anyone lacking high speed internet, working in remote locations, or requiring enhanced security has the option of bringing the ease and power of PhotoCapture to their own computers.

Carlson Point Cloud provides powerful tools for processing of point cloud files from aerial or surface sources, whether of laser or photogrammetric origin. Employ the bare earth filters to create surfaces, or use the identified above-ground cloud for feature extraction of point clusters. Use point cloud files to create profiles, sections, contours, breaklines, and finished plats, or export surface models, points, linework, etc. to CAD.

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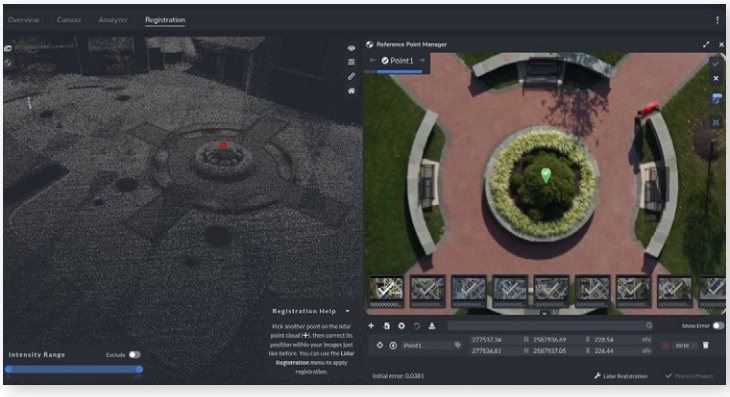

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- Survey Canvas – Virtual Drafting
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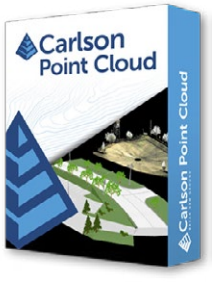
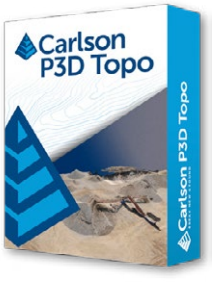


- Powerful tools such as bare earth and feature extraction
- Point clouds to finished plats
- Point clouds to profiles & sections
- Polylines to CAD



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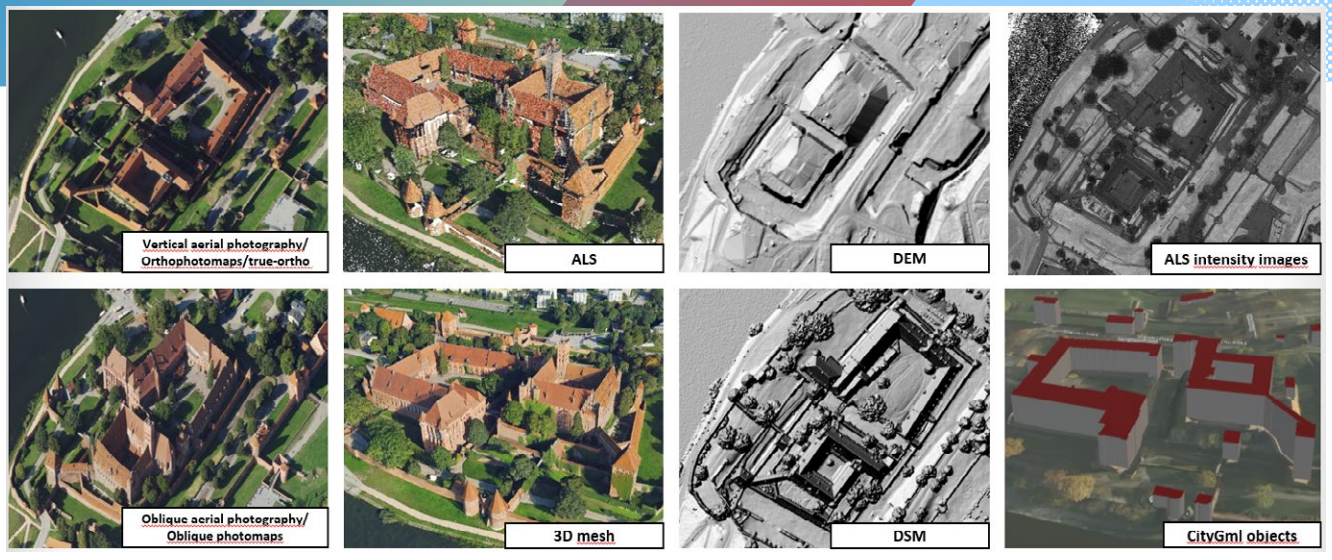


NGCR of Poland houses a comprehensive collection of geospatial data, encompassing vertical and oblique aerial imagery, orthophoto maps, lidar-derived products such as DEMs and intensity images, and advanced 3D models.

Credit: National Geodetic and Cartographic Resource (NGCR).

Perello, *continued from page 48*

In this second part of our series, we explore the diverse lidar initiatives in Belgium, Poland, Romania, Switzerland, and the United Kingdom. Each country presents a unique case study in the application of lidar technology, reflecting individual priorities and technical capabilities.

Belgium: a regional approach

Belgium's lidar coverage is characterized by regional initiatives rather than a nationwide endeavor. Each region—Flanders, Wallonia, and Brussels—has taken charge of its own territory's coverage, showcasing a decentralized approach to geospatial data collection.

Flanders

Flanders conducted its first airborne lidar mission[3] from 2001 to 2004, with a density of 0.25 points per square meter (ppsm). This initial effort aimed to facilitate the straightforward classification of ground, non-ground, and water features. Flight strips were flexibly flown based on the layout of the major river basins, ensuring comprehensive coverage of the Flemish region. Interestingly, a few cities were mapped using stereo photogrammetry, deviating from the standard lidar approach.

The second airborne lidar mission[4], between 2013 and 2015, significantly increased the density to 16 ppsm and included the Brussels area. These flights took place during winter with a 50% overlap between flight lines, focusing on first returns. The classification process was similar to the first mission, but included additional outlier filtering to improve data quality.

Wallonia

Wallonia's first airborne lidar[5] mission took place from 2013 to 2015, with a point density of 0.8 ppsm. These winter flights, with a 30% overlap, aimed to capture ground points and achieve a 1-meter resolution digital terrain model (DTM). The data was classified into five categories: off-ground, ground, high vegetation, water, and bridges, with a vertical accuracy of 12 cm.

The second mission[6], conducted between 2021 and 2022, increased the density to 6.8 ppsm. These flights had a 60% overlap and aimed to achieve a 0.5-meter resolution DTM. The data classification expanded to seven categories, adding non-classified and high-voltage lines to the previous categories.

3 vlaanderen.be/digitaal-vlaanderen/onze-oplossingen/earth-observation-data-science-eodas/het-digitaal-hoogtemodel/dhmv-i-brondata

4 vlaanderen.be/digitaal-vlaanderen/onze-oplossingen/basiskaart-vlaanderen-grb/dhmv-ii-brondata

5 geoportail.wallonie.be/catalogue/cd7578ef-c726-46cb-a29e-a90b3d4cd368.html

6 geoportail.wallonie.be/catalogue/ab14b035-c9b0-4c79-a2b6-36811fca96a1.html

	HIGH RESOLUTION *URBAN AREAS*	HIGH RESOLUTION –FULL SET *URBAN AREAS*	STANDARD *RURAL AREAS*	
	ALS + ORTHO	ALS+ORTHO+ OBLIQUE +MESH	ALS	ORTHO
	2-YEAR CYCLE	IMPORTANT NEEDS	5/6-YEAR CYCLE	2-YEAR CYCLE
Vertical aerial photography	0.05 m	0.05 m	0.10 m	0.25 m
Oblique aerial photography	-	0.05 m	-	-
Vertical orthophotomaps	0.05 m	0.05 m	0.10 m	0.25 m
True orhophotomaps	-	0.05 m	-	-
Oblique photomaps	-	0.05 m	-	-
ALS	≥ 12 ppsm	≥ 12 ppsm	≥ 4 ppsm	-
DEM	1.0 m	1.0 m	1.0 m	5 m
DSM	0.5 m	0.5 m	1.0 m	-
3D mesh	-	Tak	-	-
ALS intensity images	0.25 m	0.25 m	0.50 m	-

Standards for planned photogrammetric data collections in Poland.
The plans are published via www.geoportal.gov.pl in the layer group "Data acquisition status".

Brussels

Brussels carried out its first lidar mission[7] in April 2012, achieving a point density of approximately 30 ppsm. This mission aimed to generate a DTM and a building model at Level of Detail 2 (LoD 2). The second mission[8], in October 2021, further increased the density to about 67 ppsm, focusing on 3D modeling and potentially creating a digital twin of the city.

Innovative applications of lidar technology in Belgium include 3D building modeling using point clouds and exploration of the integration of artificial intelligence (AI) in lidar data analysis. While the current focus remains on derived products such as DTMs and digital surface models (DSMs), the future holds exciting possibilities for AI-driven insights.

Poland: a comprehensive national resource

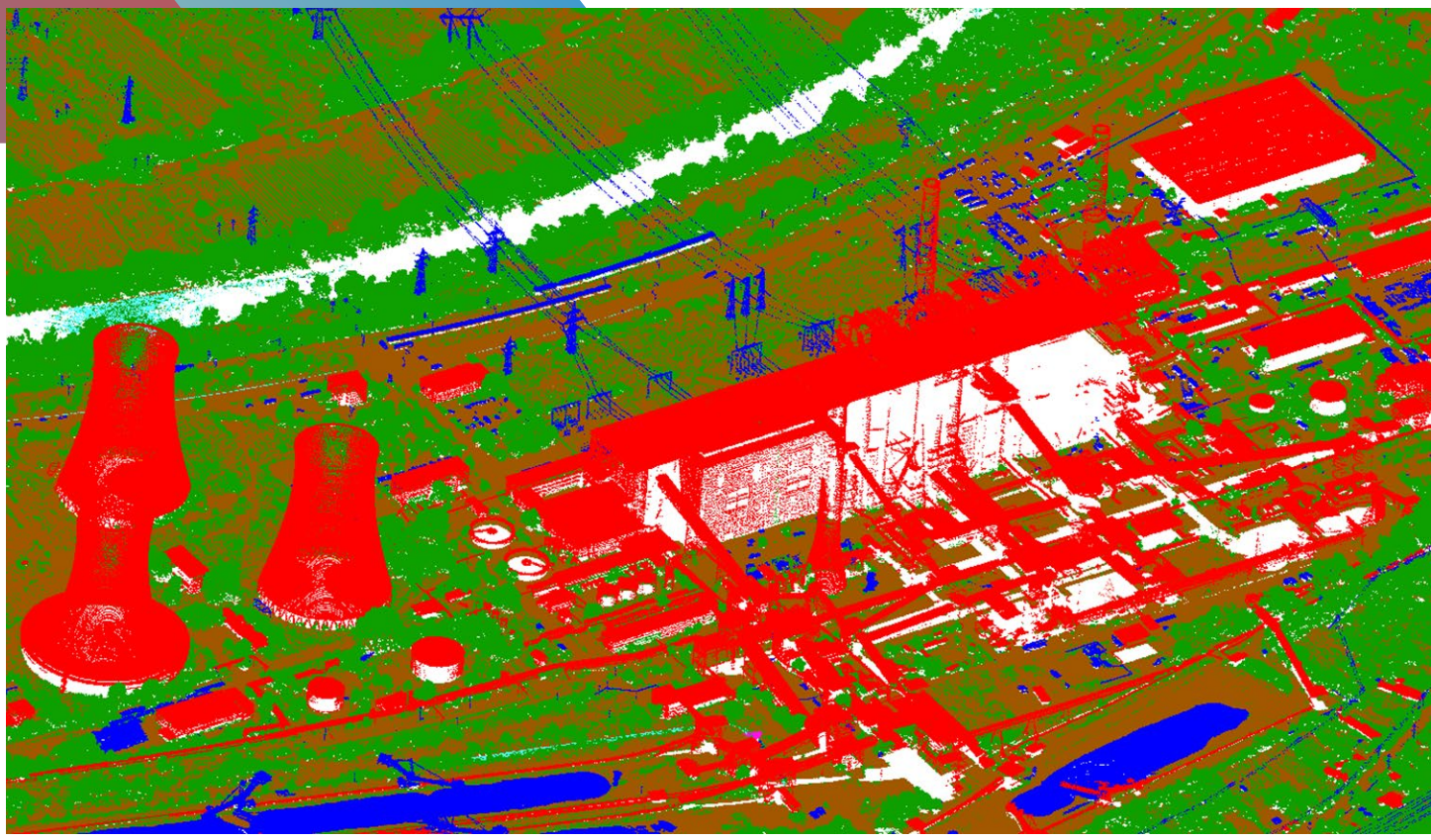
In Poland, the Head Office of Geodesy and Cartography (GUGIK[9]) maintains the National Geodetic and Cartographic Resource (NGCR), which includes comprehensive lidar data. The Geodetic and Cartographic Law places the responsibility for maintaining this resource squarely on GUGIK's shoulders, ensuring a unified national approach.

NGCR boasts a wealth of critical datasets, including vertical aerial imagery, orthophoto maps, true orthos, airborne laser scanning (ALS), digital elevation models (DEMs), ALS intensity images, oblique aerial photography, oblique photomaps, 3D mesh, and DSMs. Notably, the ALS data envelops the entire country, with urban areas receiving updates every two years.

In the years 2024-2026, GUGIK plans to acquire photogrammetric data in accordance with the three standards set out in the table above:

- high-resolution photogrammetric data for urban areas ("high resolution")

7 datastore.brussels/web/data/dataset/5cc11161-6a53-11ed-89a4-010101010000
8 datastore.brussels/web/data/dataset/ff1124e1-424e-11ee-b156-00090ffe0001
9 gov.pl/web/gugik-en



These lidar point clouds capture Rovinari power station, one of Romania's largest electricity producers, located in Gorj County near Târgu Jiu on the Jiu River.
Credit: National Center of Cartography of Romania (CNC).

- high-resolution photogrammetric data for urban areas ("high resolution—full set")
- photogrammetric data for non-urban areas ("standard")

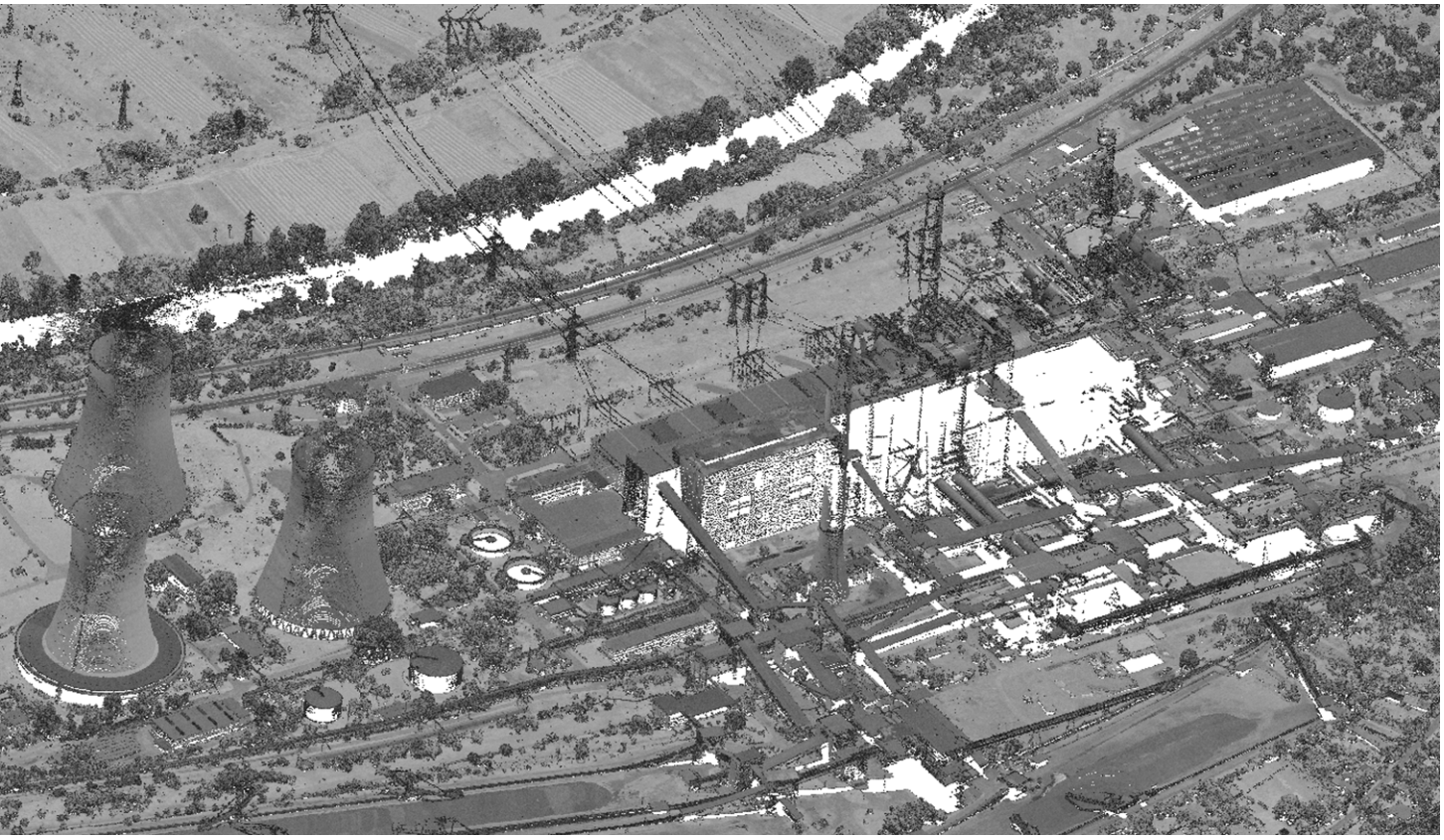
Poland is adopting two standards for lidar data collection: a minimum of 12 ppsm for urban areas (2-year cycle) and 4 ppsm for rural areas (5/6 year cycle). This balanced approach ensures high-quality data acquisition while meeting diverse needs across different landscapes and settings.

Lidar data, particularly ALS data, forms the foundation for many other crucial registers in Poland, making it a cornerstone of the country's geospatial infrastructure. Its applications are wide-ranging, playing a critical role in:

- Security and crisis management through the creation of risk and flood hazard maps
- Spatial management and urban planning
- Hydraulic modeling and environmental protection
- Forestry management
- Administration for analysis and decision-making
- Scientific research and archaeology
- Tourism development

GUGIK has ambitious plans for extensive data acquisition from 2024 to 2026, targeting high-resolution data for urban and rural areas. The agency continues to pioneer innovative lidar applications, delivering hybrid solutions that integrate aerial photography and elevation data to meet rigorous standards and address a wide array of user needs.

Poland's commitment to open data is evident in its approach to lidar dissemination. A significant portion of the geospatial data collected in the NGCR, including ALS data, is openly accessible and freely downloadable via www.geoportal.gov.pl. This initiative underscores Poland's dedication to



advancing geospatial data accessibility and utility, setting a notable example for other European nations.

Romania: balancing security and innovation

Romania's approach to lidar coverage reflects a balance between security considerations and technological innovation. The National Center of Cartography[10] (CNC) primarily focuses on quality control, while data acquisition responsibilities rest with the National Agency of Cadaster and Land Registration (ANCPI) and its data producers.

Lidar data collection in Romania is influenced by legal parameters, particularly a law stipulating that anything exceeding 9 ppsm must undergo a rigorous declassification process. According to Law 182/2002, modified by Law 167/2015, "… aerial photogrammetric recordings obtained with airborne sensors of any type operating in the electromagnetic spectrum, with spatial resolution smaller than 15 cm, and aerial photogrammetric recordings obtained with active digital airborne sensors containing more than 9 points/m^2, representing content elements relevant to national security, are considered state secrets."

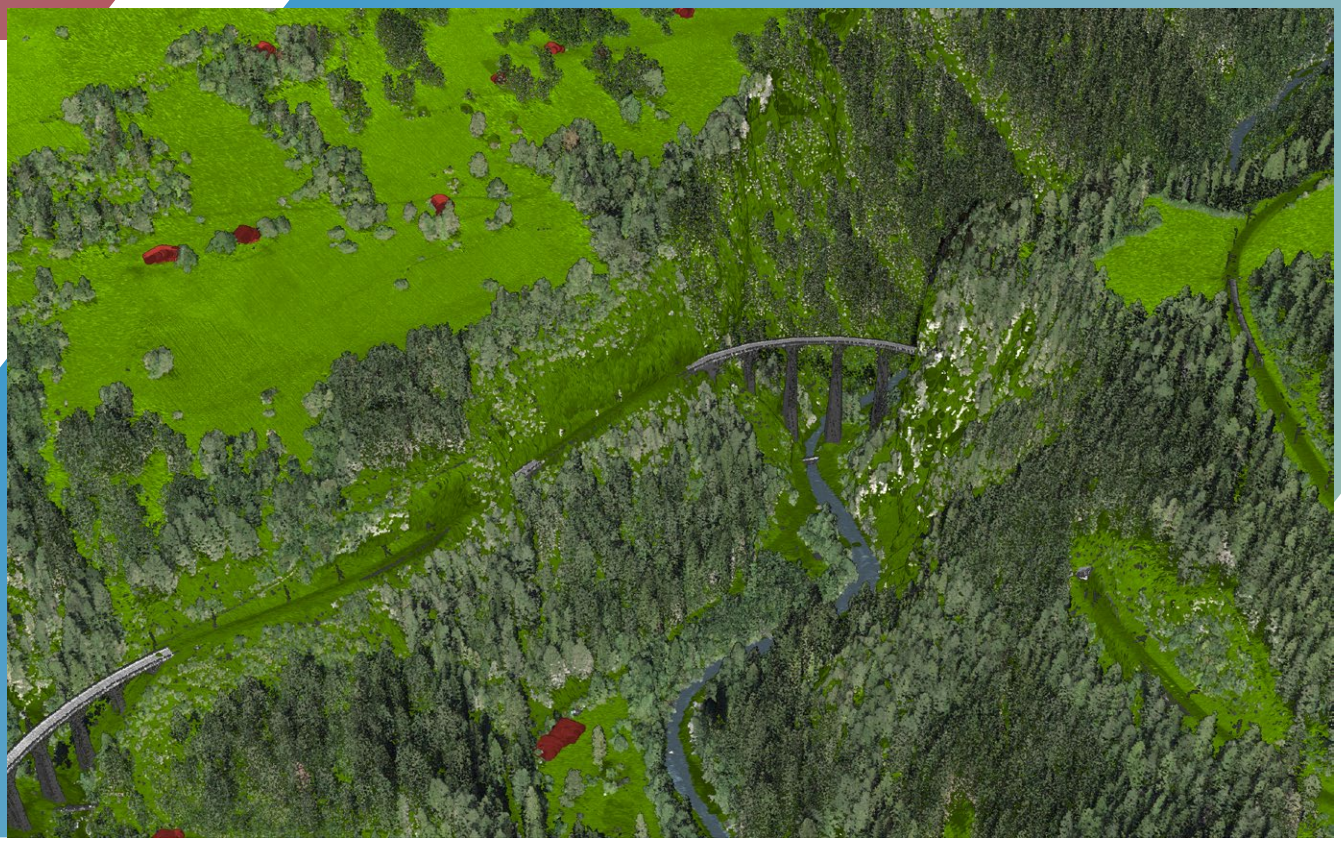
Due to these complexities, Romanian institutions often opt for lower densities. For example, the LAKI II project, completed in 2022, used 8 ppsm, while the ongoing LAKI III project (part of the Land Administration Knowledge Improvement initiative) uses 5 ppsm.

Despite these challenges, Romania is actively engaged in innovative applications of lidar technology through European projects. Two notable examples are:

1. The CARMINE[11] (Climate-Resilient Development Pathways in Metropolitan Regions of Europe)

10 cartografie.ro/index.php/ro/

11 cordis.europa.eu/project/id/101137851



The Landwasser Viaduct, a six-arched curved limestone railway bridge, spans the Landwasser River between Schmitten and Filisur in Graubünden, Switzerland. Designed by Alexander Acatos and built by Müller & Zeerleder in 1901-02, it is a key structure of the World Heritage-listed Albula Railway. Owned by the Rhaetian Railway, the viaduct stands 65 m high and 136 m long. Its southeastern abutment connects to the Landwasser Tunnel.
Credit: swisstopo.

project: This initiative aims to aid local adaptation strategies by providing decision support services and fostering multi-level climate governance. Romania's involvement includes creating a DTM for the metropolitan region of Brasov city, one of the project's case study areas.

2. The Volta[12] project: As part of this Marie Slodowska-Curie RISE action, Romania is involved in developing and validating novel processing methods for 3D geospatial data to enhance photogrammetric mapping applications. The country recently submitted another project proposal, called i-DEAL, to the European Commission, showcasing its commitment to cutting-edge research.

On the services front, Romania is prioritizing aerial photogrammetry projects, aiming to create a comprehensive catalogue of housing units listed in the cadastre. The country's geoportal hosts a variety of datasets, including aerial images and digital terrain models. While challenges persist in achieving full national lidar coverage, interested parties, such as museums and academia, can request specific point clouds for research purposes.

Switzerland: a pioneer in national coverage

Switzerland has been at the forefront of lidar technology adoption, with swisstopo[13], the national mapping agency, initiating its lidar journey in the early 2000s with the production of the cadastral survey DTM (DTM-AV), a precursor to the swissALTI3D.

In 2017, swisstopo, in cooperation with the cantons, launched a new acquisition campaign to obtain lidar data for the whole of Switzerland and Liechtenstein, spread over six years. This campaign will be concluded with the publication of the data by the end of 2024.

12 cordis.europa.eu/project/id/734687

13 swisstopo.admin.ch/en

Switzerland is currently undergoing its second complete national lidar coverage, with plans already underway for a third acquisition phase. Annually, approximately one sixth of Switzerland's expansive territory, accounting for around 7000 km², is acquired in lidar.

Swisstopo has selected an average point density of 20 ppsm for lidar data collection. The data undergoes classification into various categories, encompassing unassigned, ground, vegetation, buildings, bridges, facades, wire cables, water, and noise. The decision-making process for this density considers factors such as acquisition costs, long-term data archiving, and the limited acquisition period per year, ensuring data quality during seasons with minimal foliage and snow.

The collected lidar data is instrumental in updating swisstopo's swissSURFACE3D product. Derived from airborne lidar, this dataset comprises millions of points per square kilometer, offering a rich 3D representation of Switzerland's diverse landscape. The data characteristics include a minimum point density of 5 ppsm, with an average density ranging from 15 to 20 ppsm.

Switzerland has embraced innovative applications of lidar technology to enhance its 3D landscape modeling and ground coverage accuracy. One of the exceptional innovations involves the integration of artificial intelligence (AI) with lidar data to facilitate change detection in 3D landscape models.

Switzerland's approach demonstrates a commitment to high-quality, comprehensive lidar coverage. The country's mountainous terrain presents unique challenges for data acquisition, but also showcases the versatility of airborne lidar technology in capturing complex topographies.

> "For the geospatial industry, particularly aerial surveying companies, these diverse national initiatives present both challenges and opportunities."

United Kingdom: a devolved approach

Lidar coverage in the United Kingdom reflects its devolved administration system, with each nation—England, Northern Ireland, Scotland, and Wales—managing its own lidar programs. This approach has resulted in varied coverage and accessibility across the UK, primarily driven by environmental aspects such as flood risk mapping, coastal change, and habitat monitoring.

England

The Environment Agency has been at the forefront of lidar data collection in England since 1998. In 2015, the agency made a landmark decision to make its lidar data freely accessible to the public, empowering various sectors from forestry management to archaeological exploration and virtual reality development for gaming.

The Environment Agency National Lidar Programme[14] aims to deliver precise elevation data with 1-meter spatial resolution across all of England. In 2017, the agency divided England into 302 survey blocks for lidar data capture, a task carried out during the winter months from November to April. These initial surveys, known as Phase 1 of the national lidar programme, were conducted between January 2017 and February 2023.

To maintain up-to-date elevation data, the Agency has initiated repeat surveys of specific blocks based on ongoing needs. Each subsequent survey of a block is assigned a new phase number. Currently, there is no plan to systematically re-survey all the original Phase 1 blocks; repeat surveys are instead prioritized according to the necessity for updated data in certain areas.

The collected lidar data is published quarterly via the DEFRA Data Services survey portal. Various products derived

14 data.gov.uk/dataset/f0db0249-f17b-4036-9e65-309148c97ce4/national-lidar-programme

from these surveys are made available in 5 km tiles aligned with the Ordnance Survey grid, ensuring users have access to the most recent and accurate elevation data.

Scotland

Lidar data for Scotland is mainly provided by the Scottish Government via the Scottish Remote Sensing Portal[15]. This portal, developed in partnership with the Joint Nature Conservation Committee (JNCC), offers extensive lidar datasets for public use.

Scotland's lidar datasets have been developed through several phases, each responding to specific needs:

1. Phase I (2011-2012) covered 11,845 km² across 10 sites, aiding in flood management, archaeology, and orienteering. The point density was a minimum of 1 point/sqm, and approximately 2 ppsm on average between the collection areas.
2. Phase II (2012-2014) extended coverage to 66 additional sites totaling 3516 km². The point density was a minimum of 1 ppsm, and approximately 2 ppsm on average between the 66 sites.
3. Phases III to VI (2015-2022) captured extensive areas but still lack full national coverage. These phases have progressively increased coverage and data quality.

In addition, specific lidar datasets have been captured for Historic Environment Scotland, focusing on areas of historical significance such as Stirling, Edinburgh Old Town and New Town, and the heart of Neolithic Orkney.

15 remotesensingdata.gov.scot/about

Northern Ireland

Lidar data for Northern Ireland is accessible through OpenDataNI[16], the region's Open Data Portal. Published primarily by Land & Property Services (LPS), a branch of the Department of Finance, the available lidar datasets emphasize coverage of river basins. This data supports various applications, including flood risk management, environmental monitoring, and urban planning.

A national survey commissioned in 2022, targeting a high-resolution, 16 ppsm point density, is currently in progress.

Wales

Lidar data for Wales is provided by Natural Resources Wales and can be accessed via DataMapWales[17]. This platform facilitates the use of lidar data for various applications such as environmental management, urban planning, and flood risk assessment, ensuring that detailed geospatial information is readily available to support a range of public and private sector initiatives across Wales.

A national survey commissioned by the Welsh government was conducted between 2020 and 2024, which captured data at 2-4 ppsm. The resulting data is available as 2-meter gridded DTMs and DSMs under an Open Government License (OGL).

The UK's devolved approach to lidar coverage reflects the unique needs and priorities of each nation while still contributing to a rich tapestry of geospatial data across the country. This decentralized model allows for tailored solutions but also presents challenges in terms of data consistency and cross-border applications.

> "Europe's approach to lidar mapping showcases the continent's diversity in governance, technological adoption, and environmental priorities."

Conclusions

Europe's approach to lidar mapping showcases the continent's diversity in governance, technological adoption, and environmental priorities. From Belgium's regional initiatives to Switzerland's comprehensive national coverage, each country has tailored its lidar strategy to meet specific needs and overcome unique challenges.

The varied approaches highlight the potential for knowledge sharing and collaboration across borders. While a pan-European lidar dataset remains a complex goal due to differing projection systems and data standards, the ongoing efforts in each country contribute to a rich tapestry of geospatial information.

As lidar technology continues to evolve, European countries are finding innovative applications in climate resilience, urban planning, environmental

16 opendatani.gov.uk/
17 datamap.gov.wales/maps/lidar-viewer/

protection, and more. The commitment to high-quality data acquisition and accessibility demonstrates the growing recognition of lidar's value in addressing critical challenges and driving informed decision-making.

The future of lidar mapping in Europe looks promising, with countries such as Poland and Switzerland already planning next-generation surveys. As the technology advances and cross-border cooperation increases, we may see more harmonized approaches emerging, potentially paving the way for a more unified European geospatial landscape.

For the geospatial industry, particularly aerial surveying companies, these diverse national initiatives present both challenges and opportunities. Adapting to varied specifications and requirements across countries demands flexibility and expertise. However, it also opens doors for innovation in data acquisition, processing, and application development.

As Europe continues to refine its approach to lidar mapping, the continent stands as a living laboratory for geospatial technologies, offering valuable lessons for the global community in balancing national needs with technological advancements. The ongoing dialogue between national mapping agencies, industry stakeholders, and research institutions will be crucial in shaping the future of lidar technology and its applications across Europe and beyond.

Acknowledgments

The author is grateful for help in creating this article received from: Valéry Lemaire—Institut géographique national (ngi.be), Belgium; Anna Bober—Head Office of Geodesy and Cartography (GUGIK) Poland; Iuliana Maria Pârvu—National Center of Cartography (CNC), Romania; Roberto Artuso—Swiss Federal Office of Topography (swisstopo); and Chris O'Dwyer—Environment Agency, UK.

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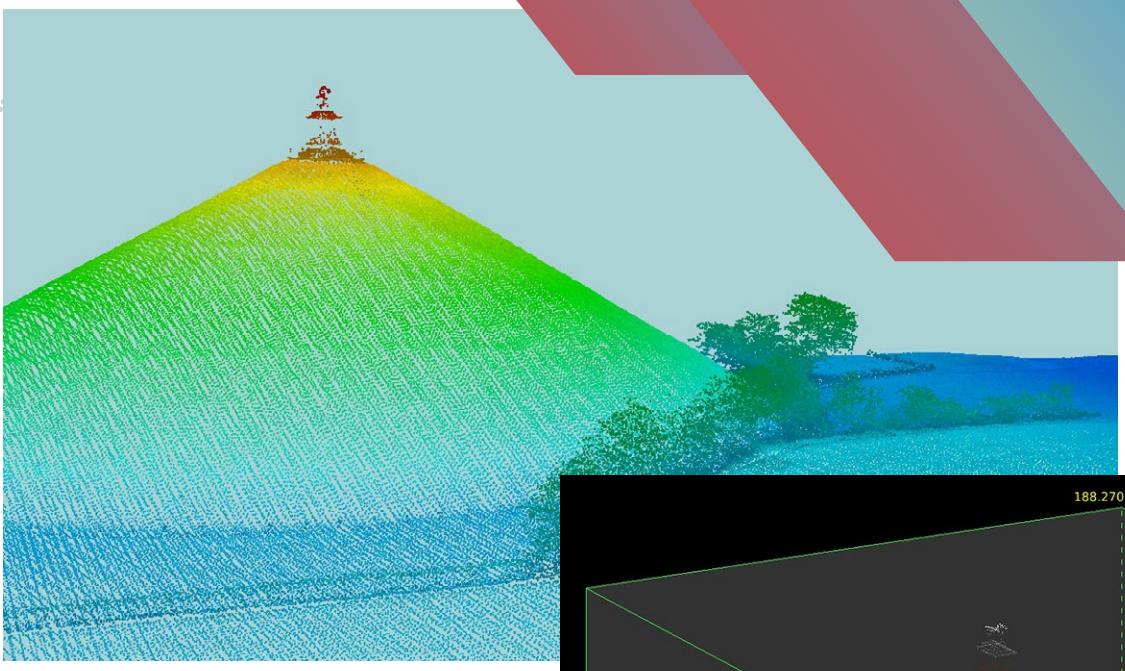

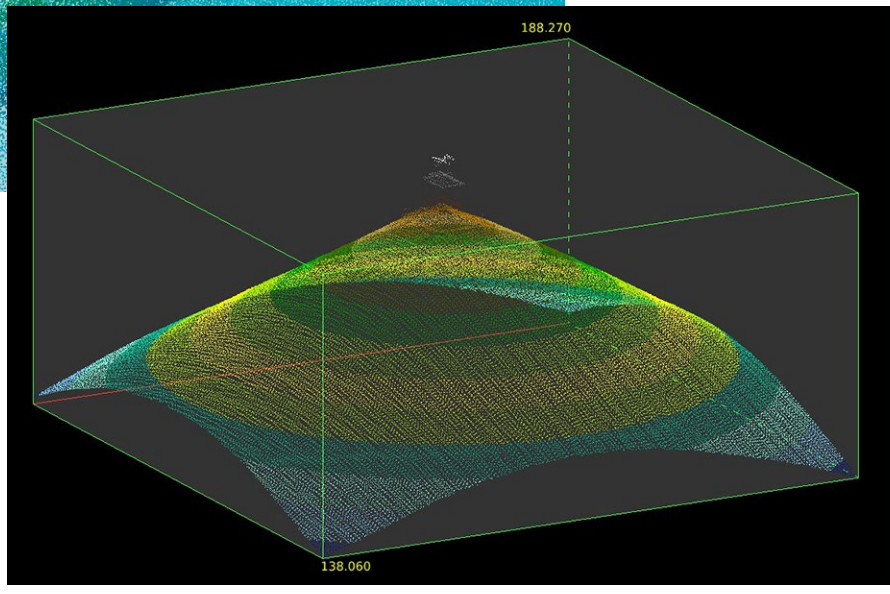

These lidar scans of the Lion's Mound at Waterloo, Belgium, vividly showcase the monument, which commemorates the Allied victory over Napoleon. Erected between 1823 and 1826, the mound is 40.5 m high with a circumference of 520 m, formed from 300,000 m^3 of battlefield soil. The cast-iron lion atop, designed by Van Geel and weighing 28 tonnes, symbolizes restored peace. This digital visualization highlights both historical significance and technological advancement in heritage preservation.

Credit: NGI/IGN Belgium.

Elevations for the Nations

Understanding Europe's varied approach to lidar mapping

PART II

BY ADA PERELLO

Mapping activities for the United States are centrally regulated for a land area of 3.8 million square miles, whereas lidar coverage of Europe's 3.9 million square miles is managed at the national level, by 50 different countries. This approach has resulted in varying levels of coverage: some areas boast extensive lidar data, while others are still in the early stages of implementation, as explained in the first part of "Elevations for the Nations"[1].

To gain a comprehensive understanding of lidar mapping across Europe, the European Association of Aerial Surveying Industries (EAASI[2]) reached out to representatives from national mapping agencies on the continent.

continued on page 40

1 Perello, A., 2023. Elevations for the nations: understanding Europe's varied approach to lidar mapping, *LIDAR Magazine*, 13(3): 41-45, Fall 2023. lidarmag.com/2023/10/07/elevations-for-the-nations/

2 eaasi.eu

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