VOLUME 10 ISSUE 3

LIDAR MAGAZINE

MAY/JUNE 2020

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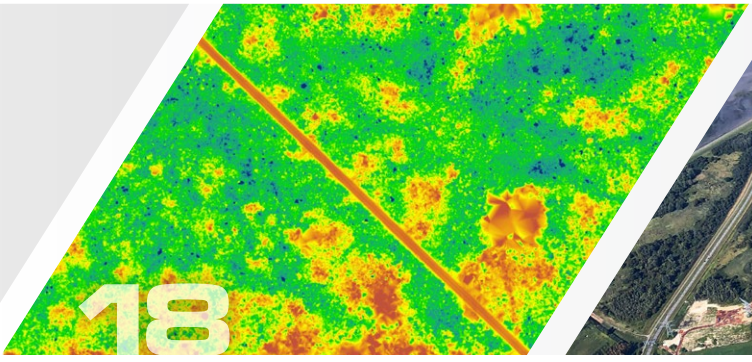

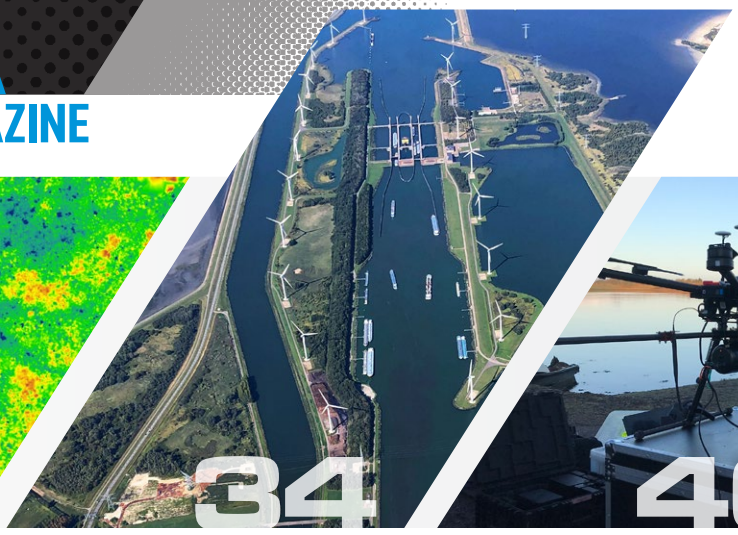

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◀ ON THE COVER
High-density lidar at 30 ppsm provides accurate modeling of the built environment and opens the door for advanced remote sensing applications. Courtesy of Quantum Spatial.

DR. A. STEWART WALKER

Keep the Home Fires Burning

Many of us continue on lock-down, while the wait for definitive good news seems interminable. Some localities and non-essential sectors of the economy in the US have permission to re-open, yet the citizenry is not entirely convinced that the risks have been adequately mitigated. It seems certain that normal life and travel are some months away and that there will be permanent changes, involving, for example, routine testing and vaccination Most of all, there are so many imponderables that it is hard to be decisive—but sinking into a slough of pessimism is unlikely to be helpful.

This issue contains an interview with Mark Meade of Quantum Spatial which is a refreshing counterpoint. His firm has almost its entire headcount working productively from home and all aircraft are flying. Doubtless, Quantum Spatial's competitors are equally adept. All these companies undertake vast projects across the US and beyond, meet challenging timelines and price levels, and, in the process, stretch the technology and uncover its capabilities. Along the way, Quantum Spatial has been acquired and is now an NV5 company. Mark's answers to our questions whet the appetite for detailed accounts in the near future!

Speaking of big US geospatial services companies, we also have articles from Surdex, discussing when customers need to refly projects with lidar, and Dewberry, on the role of topobathymetric lidar in monitoring nesting sites in Florida of the Cape Sable seaside sparrow.

We cross the Atlantic and move from big companies to small. We have previously featured the UK company Routescene[1], which manufactures a pod for UAV-lidar, and in this issue they provide an interview with their customer, FlyThru, about its UAV-lidar work and experiences with Routescene equipment. One of FlyThru's projects is set amidst fabulous scenery just north of the town of Oban in Scotland, an area well known to your managing editor. Recommended!

Many of the lidar presentations we hear or read include remarks about the vast quantities of data that are generated and how difficult it is for some users to exploit it. Many of these users work in the Esri environment and will be interested in the interview with Ron Behrendt of Beyron, a consultancy in Montana, who has prepared software to ease the flow of data from the Riegl database into ArcGIS.

I've started putting a few words on our digital site each time I listen to a webinar and will continue to do so, but my priority here is to pay tribute to the organizers, moderators and presenters of these

1 https://lidarmag.com/2020/02/05/mapping-history-routescenes-uav-lidarsolution Riemersma, G., 2020. *LIDAR Magazine*, 21-23, Jan/Feb

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events. I've enjoyed ASPRS webinars recently—one, in their GeoBytes series, on the Equal Area map projection, and another, under the banner "Virtual Cloud & Coffee" on "Machine learning with Dr. Qassim Abdullah." Qassim is ubiquitous these days, a lidar doyen: I attended a virtual public meeting of the Hydrographic Services Review Panel, which advises NOAA, and he was a new member, and a Geo Week webinar, "What's the future of lidar?", in which he was a panelist alongside Ron Roth, Jim Van Rens and Martin Flood—high-quality stuff! I logged into a webinar run by the organizers of the Intergeo conference and trade show about the use of UAVs to help the battle against covid-19. And *LIDAR Magazine* was the premier sponsor of a two-day webinar, "Right-of-Way Asset Mapping Virtual Conference Experience", focused on Fort Collins, Colorado, but with many presentations of much broader interest. There is, unarguably, a tremendous variety of top-quality fare available to help us keep up-to-date. Press releases, professional journals and trade magazines continue to arrive. We regret the lack of face-to-face contact, but we are hardly short of information.

The Geo Week conference, organized by Diversified Communications (DivCom) to co-locate ILMF 2020, ASPRS 2020 Annual Conference and MAPPS 2020 Federal Programs Conference, was postponed and relocated from Washington, DC in March to Chicago at the end of July, adding the postponed AEC Next and SPAR 3D events into the mix. This doesn't look especially promising, given the numbers in Chicago at the time of writing, and we empathize with the DivCom decision-makers. We have learned, however, that ASPRS has decided to opt out of the Chicago event and is organizing its own virtual conference for late June. ASPRS will be hosting a separate online event, "ASPRS 2020 Annual Conference Virtual Technical Program" on June 22–26. This is intended as an opportunity for ASPRS Geo Week 2020 presenters to have their work publicly disseminated and published without further delay. ASPRS will assemble technical sessions from existing ASPRS Geo Week 2020 abstracts and organize a single track of technical sessions offered as secure, access-controlled Zoom webinars from 11 am to 6 pm EDT. Poster authors are welcome to participate in the virtual program with 15-minute oral presentations based on their accepted abstract topic. ASPRS will publish proceedings in the ISPRS *Archives* from written manuscripts submitted by registered presenters who participate in the virtual program. This is a new direction for ASPRS and its emphasis on members' needs is welcome.

My verbosity ran me out of space in the last editorial, so I was unable to tell you about something that caught the eye, a short piece in the February issue of *Photonics Spectra*[2] about Scheimpflug lidar. To photogrammetrists of my vintage, Scheimpflug is an optical condition that had to be satisfied in optical rectifiers so that every point on the projection plane was in focus. Scheimpflug lidar, on the other hand, was developed by Mikkel Brydegaard Sorensen at Lund Laser Centre in Sweden about ten years ago. The purpose is to detect insects. Previous approaches used extremely unwieldy atmospheric lidar. Sorensen and two others founded FaunaPhotonics[3] in 2014, initially to develop sensors for monitoring different aerial and aquatic fauna. A Scheimpflug lidar system was the first sensor used in the company, which now works internationally on the monitoring of insects and zooplankton. Look up Scheimpflug lidar and read more about it—it's fascinating. We geospatial folk may not be doing much in terms of insect monitoring, but it's going to be increasingly important as our world changes. Another rather intriguing development that is somewhat peripheral to us mappers is the use of vertical-cavity surface-emitting lasers (VCSELs) for measuring the actions of drivers and passengers in cars[4], i.e. very short range measurements that give another input to advanced driver-assistance systems. VCSELs are used in depth sensing in devices such as smartphones, for example Apple's Face ID module, so R&D investments are supported by high-volume sales. Applications include checking for infants left in the car, or whether the driver is awake, from sensors in the rearview mirror or steering wheel. Methods of 3D sensing with VCSELs include structured light and time of flight, both with their merits and demerits. Could VCSELs be another technology that derives from automotive applications but finds a second home in geospatial? The range appears to be way too short, but lidar never ceases to surprise…

A. Stewart Walker // Managing Editor

2 Fløistrup, K.M., 2020. 3 questions with Kiri Miyaca Fløistrup, *Photonics Spectra*, 54(2): 54-55, February.

3 www.faunaphotonics.com

4 Hogan, H., 2020. Car in-cabin sensing is within sight, *Photonics Spectra*, 54(4): 32-35, April.

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Co-Located Events AEC Next, SPAR 3D, and Geo Week Pivot to Virtual Content Series for 2020

DIVERSIFIED COMMUNICATIONS

AEC Next, SPAR 3D Expo and Conference, International Lidar Mapping Forum (ILMF) and Geo Week, scheduled for a July event in Chicago, are pivoting to a series of virtual content for 2020. The change was necessitated by the ongoing health and safety issues stemming from the COVID-19 pandemic.

AEC Next, SPAR 3D, ILMF and Geo Week will produce a series of interactive virtual content throughout 2020 including webinars, virtual product showcases, industry reports, weekly news, and a virtual awards ceremony announcing the recipients of the 2020 Lidar Leader Awards.

"While we cannot come together physically this summer in Chicago as we hoped, our staff and advisory board are busy creating virtual opportunities in the coming months to connect with our global community. It's been made abundantly clear that our customers rely heavily on our events for education and to get quality leads and make business connections, and we will answer that call by continuing to provide opportunities virtually this year," Event Director Christine Salmon said.

"We are grateful to all of our customers and stakeholders for their patience and support of this move," imparts Lisa Murray, Group Director, Diversified Communications. "The team is excited to bolster efforts to connect our community virtually until we can be back together physically. The silver lining is, we have unprecedented online engagement which is introducing new audiences to our platform. This will inevitably translate to more new potential customers now and at our next live event in 2021."

Details about the 2020 virtual content and the next live event in 2021 will be announced soon. In the meantime, free webinars and reports are available online now at aecnext.com, spar3d.com, and geo-week.com.

Commercial UAV Expo Americas 2020 Shifts to Virtual Event in September

FAA Administrator Stephen M. Dickson to Keynote

DIVERSIFIED COMMUNICATIONS

Commercial UAV Expo Americas 2020 is going virtual, according to event organizer Diversified Communications. "Due to ongoing health and safety concerns stemming from the COVID-19 pandemic, members of the commercial drone community we serve have made it clear that it would be impossible to hold the live event as originally planned. In the interests of ensuring our community still has an opportunity learn from and connect with each other, we have reimagined Commercial UAV Expo Americas as a fully virtual event taking place September 15-17, 2020," said Lisa Murray, Group Director at Diversified Communications, organizer of Commercial UAV Expo Americas. These are the same dates the live event had been scheduled for in Las Vegas.

Details will be forthcoming, but the content will include keynotes, panel discussions, and presentations with interactive Q&A and chat features; an AI-powered networking component; virtual exhibits, and demonstrations by UAS solutions providers. "We have stayed in close contact with our customers over the last few months. A huge thank you to all of them. I cannot say enough about their support and collaboration with our team during this time. What is clear is that they want and need the business networking and education normally provided by our event, but travel bans and other restrictions were going to prevent them from attending. We decided to put a stake in the ground and make immediate plans to ensure the broadest participation possible by making the event virtual now. Where a virtual event may not have appealed to many just a few months ago, the world has changed. People are yearning for connections and education. We are excited to offer the key benefits they expect from us: critical, timely education delivered by industry leaders, opportunities to network and engage with peers, and the ability to learn about the newest technology in the space," said Ms. Murray. She added that the content will naturally address how the industry has responded to the pandemic, as well as the associated opportunities and challenges.

FAA Administrator Stephen M. Dickson, an aviation professional with nearly 40 years of experience, will Keynote the virtual event. Dickson leads an agency responsible for the safety and efficiency of the largest aerospace system in the world. "We are thrilled that Administrator Dickson will be addressing the audience at such a critical time for the drone space," said Ms. Murray.

Additional information about the event will be announced, but commercial drone

solutions providers will have the opportunity to host virtual exhibits, conduct one-on-one meetings, provide product information, share videos and more—all virtually. "We are investing in a robust virtual platform that will deliver high value to companies already signed on for the in-person event. We expect going virtual will naturally attract new companies, further enhancing the array of products and services on offer and attracting new buyers who may not have attended a live event but are more than ready to attend virtually." said Ms. Murray.

"So much has happened in the drone space since the last edition of Commercial UAV Expo Americas," said Ms. Murray. "People need an update on the latest developments and the impact on their business. While restrictions on travel are in place, restrictions on business are not. We are dedicated to bringing major stakeholders together to continue to move the industry forward during a particularly important time for drone industry expansion."

Return to a Live Event in 2021

In 2021, Commercial UAV Expo Americas will take place September 7-9, 2021 at the Mirage in Las Vegas," said Ms. Murray. "We look forward to the opportunity to connect in person with our customers. In the meantime, we will be their virtual connection to the drone industry."

The First Virtual Round Table for INTERGEO 2020

"Our time has come!"

HINTE MARKETING & MEDIA GMBH

The INTERGEO Round Table is the annual mid-year event for experts to discuss the latest industry trends. The participants of this get-together, which was hosted virtually for the first time, are convinced that our world needs intensified digitalisation and networking to enable us to better overcome challenges. But things don't end with the Round Table. "We want to showcase our topics live, too, and highlight their critical importance—at INTERGEO 2020 in Berlin!"

"INTERGEO 2020 is going ahead."

When INTERGEO organiser Christoph Hinte made his announcement at the start of the Round Table, smiling faces appeared on screen. The participants—experts from the worlds of business and science—welcomed the news with open arms. After all, businesses and institutions are eager to attend INTERGEO as the first live event of 2020 to showcase their innovations. "The hygiene and social distancing concept is currently being coordinated. In addition to the live event, this year is the first time we will also offer a virtual twin. Both the conference and the fair will be replicated." Hinte is optimistic: "By hosting the fair in a virtual format, we expect to attract the same number of visitors as in previous years, if not more."

The industry's time to shine

"Where does the geo-IT sector stand in terms of digitalisation and networking?" asked presenter Christiane Salbach from the German Society for Geodesy, Geoinformation and Land Management (DVW) as she kick-started discussions. Professor Jörg Blankenbach, Head of the Geodetic Institute at RWTH Aachen university, has a clear opinion on this matter: "Major existing concepts such as GIS (geographic information systems) and BIM (building information modelling), which previously existed independently of one another, are now merging at an increasing pace. One specific result of this is that georeferencing has been integrated into the latest version of the open BIM standard IFC for the first time. In other words, structural and civil engineering models are finally being docked to their geographical coordinates."

Industry representatives are saying the same thing. Although they actually come from different camps, Michael Mudra from digital solution provider Hexagon, Ralf Mosler from BIM and CAD specialist Autodesk and Janos Faust from the geospatial company Trimble all stress that reality must now shift to a shared database. For them, it's about breaking out of silos and ensuring accessible communication across different software platforms, ecosystems and, last but not least, mentalities.

Oliver Milzarek from DB Systel, the IT service provider for Deutsche Bahn AG, takes an even more pragmatic view: "Projects at Deutsche Bahn now fully depend on simulation and visualisation—even for the tiniest railway arch! That's why we need to step up to the plate. The conditions are right. Our time has come! Deutsche Bahn knows that BIM is the bedrock for sustainable planning, construction and operation. Digital twins are unbeatable when it comes to transparency, too. If we network the data properly, we will reap the benefits in all phases of construction—and still will be 80 years (a realistic lifetime for railway objects as well as for tunnels) down the line."

BY RON CHAPPLE

A Billion Points of Light

Exploring the world with aerial cinema, lidar, and images

When GEO1 interviews potential team members, one of the first questions we ask is how the candidate discovered their passion for the geospatial sector. Ironically, I have never had to answer this question personally. Turning the tables and asking myself the same question, I found that the answer took some thought…

I started out as a cinematographer, filming from a helicopter with a gyrostabilized camera, documenting aerial shots for nature documentaries. I was lucky enough to see the world from 500 feet above as our team sought out natural wonders for our viewing audience. I filmed active volcanoes in Hawaii and polar bears in the Arctic, and discovered ancient cave paintings in the jungles of Colombia. Much to my surprise, the first question most people asked when I shared the footage was, "Where were you?"—to which I rarely had a precise answer.

That essential question of, "Where am I?" developed my interest in geospatial technology. Years ago, a descriptive sentence of the location was enough. Now, we want to narrow the answer down to one or two centimeters.

As my company pivoted from aerial cinema to aerial remote sensing, I looked at our sector from a fresh perspective. What were the differences, and what was similar? We have always been collecting data from a helicopter. Whether that data is pixels from an 8K camera or 2,000,000 laser pulses every second, the end result is a data set that needs to be processed, edited, and interpreted by a larger team. Managing and manipulating that data for the purposes of analytics is similar to the general workflow of editing video clips into a feature length film. Different skill sets may be needed, but the concept is the same.

We've filmed for National Geographic, BBC, and the Discovery Channel, flown over the glaciers of Patagonia and the jungles of Colombia, and camped in an unheated tent in the Arctic Circle. How are all these experiences related to the geospatial industry? The exploration is not new, but the technology is. Like Hawaiian voyager Nainoa Thompson, who sailed the Hōkūle'a outrigger canoe from the Hawaiian Islands to Polynesia using ancient navigational techniques, we are explorers documenting the unknown. For those of us in the geospatial industry, we share the need to explore and to know where we are with centimeter-level precision.

In the coming years, exploration will take on considerable weight as we venture out into even greater unknowns, like SpaceX in their bid to "Occupy Mars". My company was honored to film the first attempts by SpaceX to land a rocket on an autonomous ship. It takes years of precise engineering to build a rocket that revolutionary, and days of planning to film the eight seconds the rocket spends hurtling through the atmosphere towards either a safe landing or an untimely demise in the ocean.

Logistics and planning are absolutely critical for any enterprise. At GEO1, we're prepared to deliver under any circumstance. This attention to detail comes from our aerial filming experience. An aerial shoot for a feature film might have hundreds of actors, expensive props, and a limited time window—you simply do not tell the director there's a problem.

The days ahead will unfold as a test of how far our own innovation can truly take us. Those of us in airborne acquisition can provide the data behind eye-opening geospatial analyses of a pandemic's impact. In addition, we have an important role supporting our communities with data and analysis to overcome racial, economic, and social injustices. As much as 'Occupy Mars' is an exciting goal, and exploring our connection with nature is always informative, our world has unprecedented challenges we need to confront. Let us come together to bring our strengths to the table. Let us reimagine the way geospatial data and analytics fit into the conversation and explore our collective future with a renewed intensity.

Ron Chapple is the founder and CEO of GEO1.

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Lidar acquisition from fixed-wing aircraft dominates QSI's flying program. In the Pacific Northwest, for example, there are often considerable challenges due to terrain and coniferous vegetation.

Quantum Spatial Survives the Pandemic

Service company leads with lidar during tough times

LIDAR Magazine accepted an invitation from Quantum Spatial Inc. (QSI) to interview senior vice president Mark Meade. Managing editor Stewart Walker conducted the interview by teleconference, hosted by Maria Bradley of Kickstart Consulting.

LM: Mark, it's great to be talking to you again. How are you, and Quantum Spatial, doing in the current crisis? Your CEO sent a very positive and optimistic letter to customers and partners on 17 March saying that you were weathering the storm.

MM: We are doing remarkably well, especially given these very challenging times. Two keys to our success were early recognition of the threat and swift action. We started monitoring the coronavirus outbreak in February about, the same time as the country recorded the first virus-related death, and immediately activated our business continuity plan. Our plan includes a specific response action framework for a pandemic. I serve

BY DR. A. STEWART **WALKER**

Mark Meade, senior vice president, QSI

on our Response Task Force and we have been meeting weekly for two months.

The safety and security of our employees and the communities in which we operate continue to be our top priority. We took action in most locations before government mandates. Moreover, serving the mission of each of our clients is also key, and we haven't missed a step.

Our success is a testament to our professionals across all job functions—from acquisition to IT to our project management and production teams. It is amazing to look back at the last three months and reflect on the changes we've witnessed. We have found new ways to accomplish many things from home without the need to travel. And we have added new words to our vocabulary. Zoom takes on a whole new meaning for all of us.

We have continued to execute at the high level required for the essential nature of our work. But I don't want to lose sight of the overall damage to our economy, the number of lives lost in this pandemic, and the unique cruelty of this virus. My hope is that we learn a lot from this and change the way we live our lives and run our businesses.

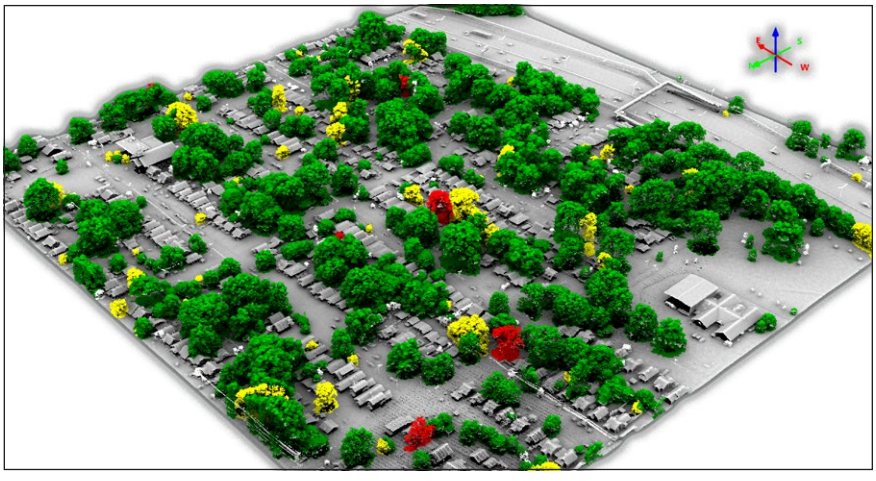
LM: What percentage of your employees are successfully working from home? Indeed, your software development manager recently posted tips about this on your website.

MM: Some of our professionals have been working from a home office for years. The lessons learned have really helped the rest of us these last few months. Jeff Skahill's post that you mention was both valuable and timely. Our eight physical offices are largely empty today. There are two general exceptions: small teams that receive raw data shipped from our acquisition crews who must put this data through the paces of QA/QC immediately to ensure it will meet client requirements, and the individuals who package and ship the final deliverables. Otherwise, about 95% to 98% of our staff is now working from home. Maintaining social distancing among our 620 employees is really important for us to help flatten the curve.

LM: *LIDAR Magazine* understands that many of your production, sales, marketing and back-office staff can work remotely, but what about your aircrews? How do you operate aircraft that need more than just a pilot? How do you collect data? How do you organize refueling and maintenance?

MM: Acquisition is completed with an air crew that includes a pilot and sensor operator. The operator is in the back of the cabin with the sensor and flight management system. We continue to operate as per all CDC, federal, state and local guidelines for businesses conducting essential services. We have provided crews with all the tools recommended by the CDC, including masks, disinfectant, gloves and hand sanitizer.

The logistics for acquisition have become more challenging. We have moved away from hotels to residences, securing private accommodations. This allows us to avoid crowds and provides kitchens for the preparation of private meals. Most airports are operating on a regular basis and we have a large hangar



Hyperspectral imagery was fused with high-density lidar, allowing us to group lidar returns for each tree, and assign species health from the hyperspectral data to the 3D tree representation

and our own highly qualified staff of mechanics in Sheboygan who take care of most of our major maintenance. Acquisition is more challenging today, but our flight management team is doing a terrific job navigating those challenges.

LM: Despite the pandemic, you are working on many projects. Can you give us a flavor of some of the most exciting ones? Are there any obvious trends in the type of business you are winning, e.g. less vectors/more orthos, less imagery/more lidar, less airborne, more UAV, bigger areas, higher resolution? I listened to the Geo Week webinar last week and the message about lidar certainly was higher density, more frequent data collection, bigger areas, lower cost.

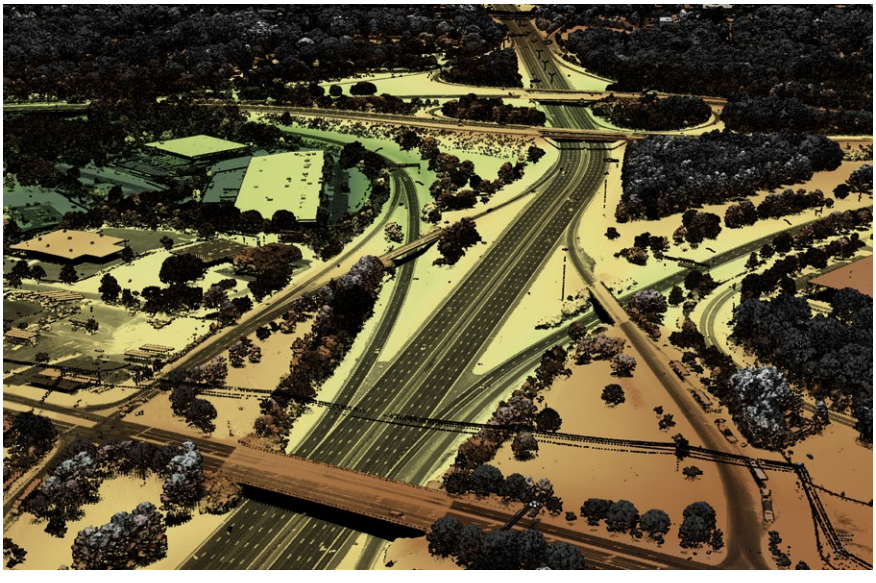
MM: Our scale and the diversity of our solutions enable us to work on many incredibly exciting projects. We just completed a very large project that fused hyperspectral data with high-density lidar to identify the species and health of deciduous vegetation. This was specifically related to ash trees that are falling prey to the emerald ash borer and serve as a major risk to above-ground infrastructure for electricity. We were told this was the largest high-resolution hyperspectral project ever undertaken anywhere in the world.

In terms of scenic locations, few projects can compare to the natural beauty of Yosemite National Park. We are nearing the completion of 1243 square miles of lidar there at QL1 specifications. We couldn't resist flying Half Dome and El Capitan at much higher densities. We have 60+ ppsm lidar point clouds in those limited areas and the detail is spectacular. Finally, the engineer in me enjoys a deep dive into the data. We just completed acquisition

UAVs provide considerable capabilities for smaller project areas that require high-accuracy, high-density point clouds from lidar

of three independent datasets for a two-mile corridor for a Department of Transportation. From that we have traditional lidar captured at 600 feet from a rotary platform; nadir and oblique imagery, and high-density lidar captured from our new comprehensive low altitude sensor solution (CLASS) pod, at 500 feet from rotary; and ultra-high-density lidar captured using a UAV platform from 250 feet.

In terms of the market trends you mentioned, more orthos and less vectors has been in place for years. But vectors still have their place in certain applications. Lidar and the downstream analytics from these data account for about 75% of our revenues. For us, fixed wing acquisition dominates, rotary is significant, and UAVs are used in limited but important applications, as is ground-based mobile mapping. Higher densities make great headlines for all the right reasons and provide extreme value. And large project areas are the norm as the benefits of the data are clearly understood. We completed about 175,000 square miles of wide-area lidar coverage and 75,000 linear miles



High-density lidar at 30 ppsm provides accurate modeling of the built environment and opens the door for advanced remote sensing applications

of lidar for electric and natural gas lines last year alone.

The Geo Week webinar about lidar was spot on. But I suggest there is more, and this addition is critically important. We have been investing heavily in developing complex algorithms and analytics that allow us to extract added value and more informed answers from these point clouds. The first two drivers you mentioned—higher density and more frequency—open the door for many advanced applications.

LM: Owing to Covid-19, geospatial professional and conference programs have been canceled or postponed. How is that affecting you?

MM: The impact is significant. We typically exhibit at 90 conferences each year and attend 60 more. Over the last two months we have seen cancellation or postponement of all of these stretching to midyear. Typically, these conferences provide a venue for us to visit with clients, hold key meetings with tech providers, catch up with our partners, and expand our knowledge base by attending technical programs. These functions continue, but all virtually as of now.

Our senior leadership team has been conducting virtual meetings since 2013. Similarly, our customer focused team leaders are geographically dispersed and make great use of virtual meetings. We have extended these practices to meet the diverse needs in all other areas. Some of these new practices are sure to replace old ones as we move into the future.

LM: At the end of last year, it was announced that [and I'm just quoting bits of the press release] NV5 Global, Inc., a provider of professional and technical engineering and consulting solutions, had acquired Geospatial Holdings, Inc. and its subsidiaries, including QSI, the nation's largest independent geospatial analytics firm. NV5 acquired QSI in an all-cash transaction for approximately $318 million. NV5 expects the acquisition to expand and diversify NV5's customer base to include new federal, state, and commercial clients in the high-growth geospatial data analytics market. Please comment. Are there any other companies in the NV5 portfolio with which QSI has discovered synergies?

MM: The sale of QSI by Geospatial Holdings, Inc., to NV5 was completed near the end of 2019. Geospatial Holdings, Inc., was the parent company of QSI. We just finished our first full quarter as an NV5 Company. The transition has gone really well. NV5 has acquired several other large companies over the last few years, and their experience with those transactions has been key to our successful integration. The core values of NV5 and QSI are incredibly similar, and that too has been quite important.

> "We have identified a number of opportunities for additional synergies, which we are currently pursuing and implementing, particularly in support of utilities..."

I am really encouraged by the expertise and professionalism of everyone at NV5 that I have met and the overall capabilities of the offices I've visited. They have been very welcoming and I love the diversity across their five verticals. NV5 and QSI have worked on many projects together over the last couple of years, so there were synergies already in place before we even joined NV5. We have identified a number of opportunities for additional synergies, which we are currently pursuing and implementing, particularly in support of utilities, which is a key market for NV5 and QSI.

LM: It was announced on 2 April that QSI had been selected as a prime consultant for a five-year, $40 million shoreline mapping support services contract for the NOAA National Geodetic Survey (NGS). QSI's expertise in the collection of topobathymetric lidar and the associated data analytics is a critical capability NOAA seeks to leverage as they continue to monitor coastal resources and ensure the safety of navigation. Please tell us more about this success. From what you said in the teleconference, you have flown a huge area for NOAA already!

MM: Our April selection was as one of four companies that will perform NGS shoreline mapping over the next five years. The maximum contract value for all firms combined is $40 million.

Your comment at the end is regarding an $18.6 million task order recently awarded under a previous contract with NGS. Acquisition was recently completed and we are well into production. This task order includes collection and processing of topographic and bathymetric lidar data and aerial imagery along the North Carolina coast, the Florida Panhandle, Guam, and portions of the Commonwealth of the Northern Mariana Islands.

QSI's Autonomous Roving Inspection System (ARIS) remotely acquires lidar, RGB imagery, and thermal infrared data for electric substations

LM: I had the privilege to be invited to your Acquisition Summit 4.0 in Corvallis last October. It was a superb meeting and I hope that I am invited again. We learned about QSI's sophisticated flight planning and about some exciting QSI initiatives, for example: a multi-sensor system in a pod for helicopter use along corridors; a robot for acquiring data inside electrical substations; a rapid response capability; an increasing focus on topobathymetric lidar; and the growing demand for hyperspectral data and information derived from it. Could you comment on how some of these are moving forward?
MM: Your return invitation is in the mail (but don't buy your airline ticket yet, for reasons I will soon explain). Hosting the Acquisition Summit is truly rewarding. Last year we brought 174 acquisition professionals together from around the world for the event. I have known many of these folks for much of my professional career and have an immense level of respect for what they do and how they do it. The Summit provides the perfect venue for us to share our knowledge and technological advances with our acquisition partners and grow our overall capabilities.

All the initiatives you mentioned are either ahead of schedule or complete. Our multi-sensor CLASS solution has completed several hundred hours of rotary acquisition of nadir RGB and NIR imagery, forward-looking RGB oblique imagery, and high-resolution, high-accuracy lidar from the integrated sensors. We are now fabricating our CLASS II sensor, which will be deployed soon with upgraded models of Phase One cameras and the new Riegl VUX-240 sensors.

We have deployed 10 Autonomous Roving Inspection System (ARIS) robots that collect lidar, multispectral imagery and thermal infrared data from a small ground-based robotic platform. They are deployed in electric substations and reduce the need for boots on the ground.

Our rapid response capability has been used on several projects and, for near-real-time turnaround, the capabilities are significant. Earlier I mentioned the world's largest hyperspectral project. Hyperspectral provides the ultimate source data for complex applications of remote sensing.

LM: Participants at the Acquisition Summit last year were given copies of your company's book, *Captured in Time*. Could you tell us more about this project, designed to bring the beauty of the Earth, captured from aerial photography, to a wider public?
MM: We typically complete projects in all 50 states and many international locations over the course of a year. One month we are in a helicopter over Kilauea capturing the eruption, the next collecting fixed wing data in Yosemite, then flying ancient Mayan archeological ruins in the jungles of Honduras. Our opportunities for capturing stunning work-related images are limitless.

Our professionals in the field and office know we love to share the truly unique beauty of nature and engineering wonders with our clients and peers. *Captured in Time* provided the perfect canvas to do so. It helps communicate the value of the data we acquire, the unique beauties of this vast world, and the way we use our acquired data to develop the answers our clients demand.

LM: Are you planning to run the Acquisition Summit in 2020? How do you think things are looking?

MM: We have dates on hold for early September in Big Sky, Montana. Obviously Covid-19 and the associated health risks and economic impacts are still very much in the mix. We don't know how this will play out, but plan to make the final call in early July for this year's event. Stay tuned.

If we can't do an in-person Summit, then we plan to hold a scaled-down virtual meeting around the same time. That will make the 2021 Summit a grand celebration when Covid-19 is only a distant memory for all of us.

LM: Mark, I understand that you have just been appointed as a member of NGAC (National Geospatial Advisory Committee), which is a Federal Advisory Committee sponsored by the Department of the Interior. NGAC is authorized under the Geospatial Data Act of 2018 and reports to the Chair of the Federal Geographic Data Committee (Secretary of the Interior). Please tell us about the work of this important committee and how you expect to contribute.

MM: I am both excited and humbled by the appointment. This profession has been very good to me over the last 36 years and I see this as a great opportunity to give back. When I received the official notice a couple of weeks ago, I was especially appreciative to see the full list of committee members. I have worked with many of them at different points in my career. It is a terrific group that I respect greatly.

The committee is charged with providing advice and recommendations for federal and national geospatial programs, the National Spatial Data Infrastructure (NSDI), and reviewing and commenting on geospatial policy and management issues. I really look forward to being actively engaged in this work.

LM: We first met serendipitously when you (working for Photo Science at that time) were in Emeryville, California, to work on the integration of a company you acquired, HJW Geospatial. QSI itself is the result of M&A. Can you comment not only on the successful creation of QSI from mergers but also on the integration of the various companies you have acquired? How does QSI divide up its operations across its multiple sites?

MM: Yes, that was in 2011. Quantum Spatial was created a couple years later from the merger of three of the nation's largest geospatial firms—Aerometric, Photo Science and Watershed Sciences. Aerometric and Photo Science had each acquired many firms over their history and HJW Geospatial (Photo Science) and Mark Hurd Aerial Surveys (Aerometric) trace their roots back to 1930. Mark was a fighter pilot in WWI and actually built one of the first aerial cameras after leaving the service in 1922. We still retain that today. Finally—and I find this amazing—together we have completed more than 250,000 hours of fixed wing acquisition since our humble beginnings 90 years ago.

Each of the three firms brought significant and complementary capabilities to Quantum Spatial and all have contributed in their own way to our combined success. All offices have individual personalities, but also share our corporate values like operating with integrity and accountability; delivering uncompromising quality; and finding a better way.

In an overly simplistic way, St Petersburg, Florida, specializes in GEOINT and coastal remote sensing; Lexington, Kentucky, on medium- and high-density wide-area lidar and

The lava flow from the 2018 eruption of Kilauea on the Big Island of Hawaii clearly shows the destruction from the eruption

multispectral imagery; Dulles, Virginia, has a long history with airports and the A&E market in general; Sheboygan, Wisconsin, is the heartbeat of our airborne operations; Portland, Oregon focuses on our commercial clients with technical specialization in corridor lidar and hyperspectral and thermal infrared analytics. Corvallis, Oregon is our center of expertise for topobathymetric lidar and high-density wide-area lidar; Anchorage focuses on many technologies and the unique (spectacularly beautiful) Alaska landscape; and, finally, Bangalore has significant experience and unique skill sets in photogrammetry, lidar, utility analytics, and BIM.

Few projects garner as much attention as our ground surveys for the lidar acquisition at the Copan archaeological site of the Maya civilization in Honduras

LM: While we are very interested in all the above answers, we are *LIDAR Magazine* . Could you comment on where you are with lidar? Have you acquired new sensors recently? Where is lidar technology going? What are your big lidar goals for 2020 and 2021? Are you involved in 3DEP?

MM: We work closely with all lidar manufacturers to stay abreast of sensor capabilities and the pathways to improvement. We continuously invest in new technology and over the last 24 months alone have added eight new top-of-the-line terrestrial and three topobathymetric lidar sensors to go along with our suite of 10 multispectral, three hyperspectral and two thermal cameras.

Obviously lidar is a real differentiator for us. Yes, we have been immersed in the USGS 3DEP program from the beginning. It is an incredibly well-run program that delivers significant benefits to the public and private user communities. Recent contracts for topobathymetric lidar solutions have included projects for the USGS and NOAA (and many other clients) for nearshore and riverine environments.

Lidar will continue its impressive technological arc. All sensor manufacturers invest heavily in R&D and continue to provide the professional community with improved technology. These improvements generally fall into broad categories of operational efficiency and advanced capabilities, typically in the way of higher pulse repetition rates, better feature detection, innovative scan patterns, and improved performance in areas of significant terrain or dense vegetation.

LM: Finally, Mark, are there particular projects in the pipeline that you feel would make super articles for *LIDAR Magazine*? We want to cover them.

MM: Yosemite and the Department of Transportation project are the first to mind in terms of topographic lidar applications. Both check a lot of boxes in terms of general interest and scientific relevance. I also think we have several topobathymetric lidar projects that would be interesting to your readers. Let's work together to maximize the value of these to the professional community.

LM: Mark, thank you very much for spending time with *LIDAR Magazine*. We wish you well in working through the pandemic and prospering in the restart. We look forward to news about Quantum Spatial as the months go by.

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.

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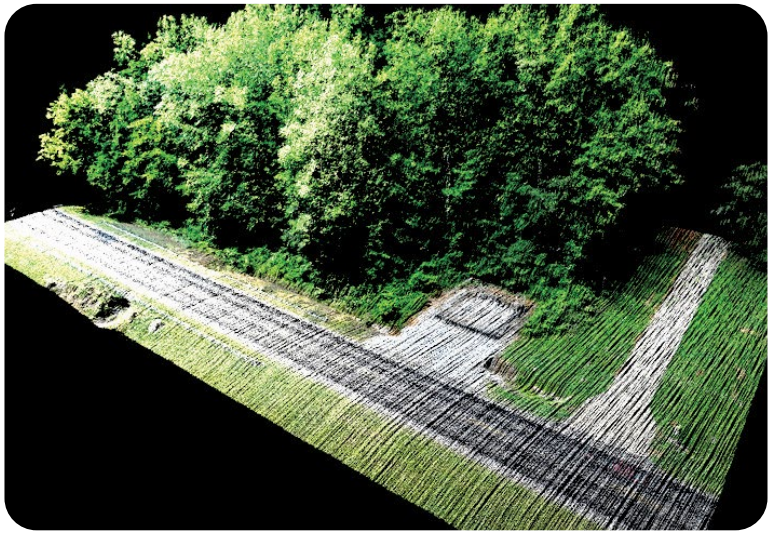

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Figure 1: A Cape Sable seaside sparrow perched on sawgrass in the Everglades National Park.
Photo courtesy of National Park Service.

Green Laser is Helping to Save an Endangered Sparrow

Topobathymetric lidar fits the bill to monitor nesting sites

The Cape Sable seaside sparrow, *Ammodramus maritimus mirabilis* (**Figure 1**), one of nine surviving subspecies of seaside sparrows (the Dusky seaside sparrow was declared extinct in 1990), is endemic to southern Florida and is listed as endangered under the current Endangered Species Act[1]. While the subspecies of the seaside sparrow are distributed generally along the east coast of the U.S. (**Figure 2**), from Massachusetts to southern Florida, and along the Gulf coast, from southeast Texas to the west coast of Florida, the Cape Sable seaside sparrow is found primarily in the Everglades National Park (ENP).

1 https://www.fws.gov/international/laws-treaties-agreements/us-conservation-laws/endangered-species-act.html

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A key element for the Cape Sable seaside sparrow's survival is the short hydroperiod pattern that maintains the wet prairie plant community. The preferred nesting habitat of this ground-nesting species appears to be a mixed marl prairie community that often includes muhly grass. The birds build cup-shaped nests about 10 – 12 centimeters (cm) above the ground and, hence, the nests are subject to flooding when water depths reach above 10 cm. Pimm *et. al.*[2] suggest that nesting will not be initiated if water levels are at a depth greater than 10 cm during the spring breeding season. The normal hydroperiod, consisting of regular but brief rainfall events, usually maintains the surface water levels at or below the ground-level.

The Cape Sable seaside sparrow's short hydroperiod wet-prairie habitat is contained entirely within the Central and South Florida Project's 4.6-million hectare footprint, which includes ENP (**Figure 2**). The two major Cape Sable seaside sparrow sub-populations occur within the park; one west of Taylor Slough and the other west of Shark River Slough in the Big Cypress National Preserve (**Figure 2**). The Everglades Multi-Species Recovery Plan for South Florida (2019 revision)[3] identified several areas for study to enhance the breeding habitat for the birds. Special attention was given to (1) altering

Figure 2: Everglades National Park and pilot project area; inset shows distribution of extant sub-species of the seaside sparrow.

current water management practices, (2) studying the existing breeding habitats, and (3) potentially restoring additional habitats. However, without accurate topographic maps of ENP, managing the hydroperiod and restoring additional habitat for breeding would not be possible. In the wet prairie, the ability to measure shallow water depths and small changes in topography is critical to the ENP's effort in restoring nesting habitat for the Cape Sable seaside sparrow.

Enter topobathymetric lidar sensors

Conventional airborne lidar technology was developed using lasers in the near infrared range—1064 nanometers (nm)—of the spectrum to measure topography. As a result, the laser pulses are of long duration and are nearly totally absorbed by water, or, at best, only the nadir pulses over water are returned to the sensor. By frequency-doubling the laser to 532 nm (within the visual green range of the spectrum), adjusting the emission angle and decreasing the pulse duration from the emitter, laser pulse penetration through water, and hence bathymetry, was achieved. These "topobathymetric" lidar sensors are ideal for mapping through the water and emergent vegetation in ENP. Most critically, the green lasers in combination with infrared lasers also measure the water surface and can identify and measure areas, when wet, that do not exceed the critical 10 cm water depth for Cape Sable seaside sparrow breeding.

In 2016, the U.S. Geological Survey (USGS) and the National Park Service (NPS) contracted with Dewberry to perform a topobathymetric survey of the 1211 square miles of the ENP (Eastern

2 Pimm, S.L., K. Balent, T. Brooks, J. Curnutt, T. Fenn, N. Fraley, S. Killeffer, J. Lockwood, L. Manne, A. Mayer, M.P. Nott, G. Russell, and E. Stanton, 1996. Population ecology of the Cape Sable seaside sparrow, draft report. Unpublished report prepared for the U.S. National Park Service and the U.S. Fish and Wildlife Service, Vero Beach, Florida.

3 South Florida Multi-Species Recovery Plan, 2019. https://www.fws.gov/verobeach/ListedSpeciesMSRP.html.

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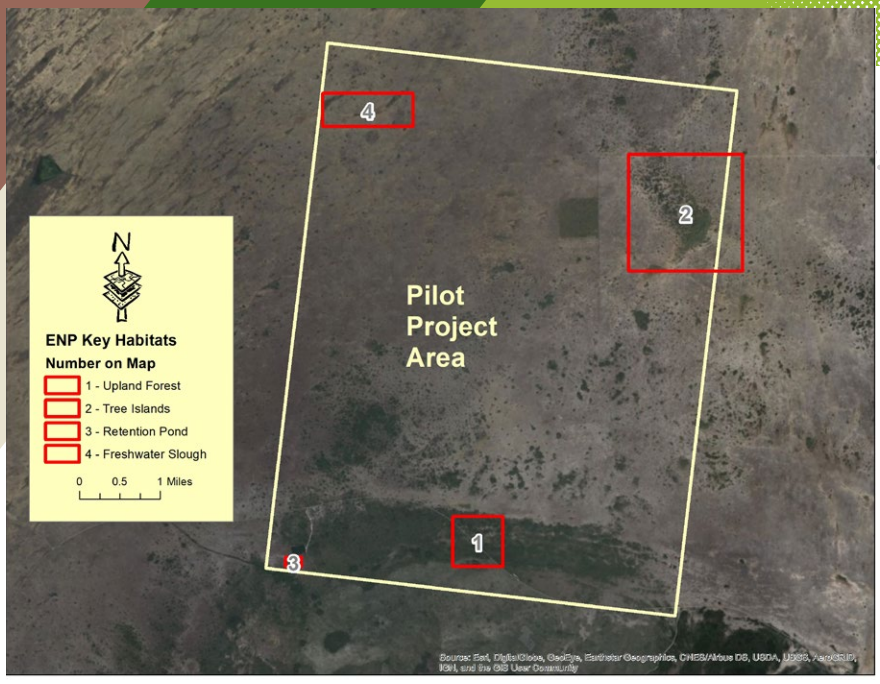

Figure 3: Everglades National Park pilot area showing acquisition plan.

Everglades) in south Florida (**Figure 2**). The project specifications followed the USGS Lidar Base Specifications 1.2 for Quality Level 1 (**Table 1**).

Dewberry is unique among lidar-data providers, in that the firm does not own or operate any sensors: with multiple different topobathymetric lidar sensors available through sub-contractors, it could choose the best sensor for the ENP project. After narrowing down the options to two sensors, Dewberry suggested a novel approach to NPS—perform a pilot project using both sensors flown over the same area to make the decision. USGS and NPS agreed to the plan, a 33-square-mile pilot area was selected (**Figures 2 and 3**), and two independent lidar acquisition missions were planned (**Table 2**).

The pilot project

In collaboration with ENP, Dewberry identified a pilot project area to include as many different habitat types as possible for testing the lidar sensors' ability to model the terrain. After consideration, four habitats, (1) upland forest, (2) tree island/marsh, (3) retention pond (open water), and (4) freshwater slough/prairie, were chosen as representative habitats, including critical vegetated wet prairie, marsh, and tree island habitats for nesting seaside sparrows. The 33-square-mile area of interest (AOI) (**Figure 3**) was selected and the pilot project acquisitions were performed between May and June of 2016. The National Oceanographic and Atmospheric Administration (NOAA) conducted the VQ-880-G mission and Leading Edge Geomatics conducted the Titan mission.

Pilot project—results

To analyze and compare the lidar data from the two sensors, Dewberry used Esri ArcGIS Desktop with the 3D Analyst extension. Classified lidar (LAS) data were built into LAS Datasets and Esri Terrains were constructed for visualization and analysis. Bare-earth digital elevation models (DEMs) were extracted from the Terrains to visualize comparisons.

As the goal of the pilot project was to assess the sensors' ability to discern breeding habitat for the Cape Sable seaside sparrow, the critical components included: (1) each sensor's ability to model ground measurements at a sufficient density to be confident of the DEMs constructed to predict suitable habitat, and (2) the ability of the sensor to accurately measure the ground through dense vegetation, tree islands, and marshes to assess the 10 cm water depth.

With regard to pulse density, while both sensors were capable of greatly exceeding USGS specifications for QL1 lidar data, the VQ-880-G sensor recorded 60% more green (532 nm) returns than the Titan over the pilot area (**Table 3**). Notably, the Titan, with two near-infrared (NIR) channels operating at a higher pulse frequency than the VQ-880-G, recorded almost five times the number of NIR pulses as did the VQ-880-G (**Table 3**).

To evaluate the sensors' performance in critical breeding habitats, DEMs were generated from the green and NIR channels in heavily vegetated and tree island/marsh habitats. The DEMs constructed in the heavily vegetated areas were very similar (**Figure 4**) with some minor differences that were

Table 1: USGS Quality Level 1 specifications for Everglades National Park Lidar	
Aggregate nominal pulse spacing	≤ 0.35 m
Aggregate nominal pulse density	8 pulses/m^2
Non-vegetated vertical accuracy (swath & DEM)	RMSE$_z$ ≤ 10 cm
Non-vegetated vertical accuracy (swath & DEM)	≤ 19.6 cm @ 95% confidence level
Vegetated vertical accuracy	≤ 30.0 cm @ 95th percentile

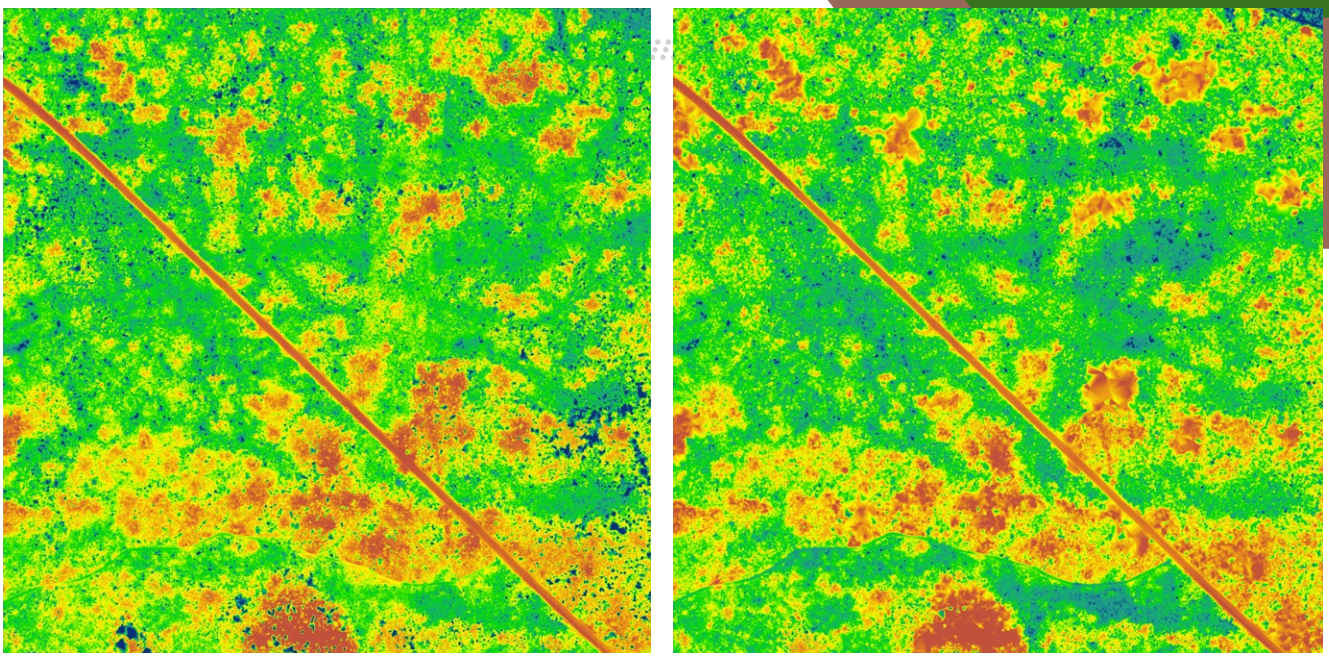

Figure 4: DEMs (bare earth) constructed from green returns from VQ-880-G (left) and Titan (right) in heavily vegetated areas in the ENP (lower elevations in blue; higher elevations in red). The distinctive linear feature from northwest to southeast is an elevated hiking trail.

Table 2: Flight details for the Everglades National Park pilot project to compare two "green" laser sensors

	Riegl VQ-880-G	Teledyne Optech Titan
Flight Dates		
400 m AGL	5 May 2016	15 June 2016
1000 m AGL		16 June 2016
Characteristics	Combined topobathymetric airborne laser scanning system Full waveform sensor	Combined topobathymetric airborne laser scanning system Full waveform sensor
Laser frequencies	Narrow-beam 532 nm (green) laser Integrated 1064 nm (NIR) laser	532 nm (green) laser (independent) 1064 nm (NIR) laser (independent) 1550 nm (IR) laser (independent)

Table 3. Overall data density in the 33 square mile pilot area for green and NIR channels from both VQ-880-G and Titan sensors

Sensor/Wavelength @ 400 m AGL	All points	Pulse density (pulses/m^2)
VQ-880-G: 532 nm (green)	2,304,807,470	21.74
VQ-880-G: 1064 nm (NIR)	582,050,671	5.65
Titan: 532 nm (green)	1,390,234,830	14.22
Titan: 1064 nm + 1550 nm (NIR)	2,797,517,022	28.55

attributed to acquisition date. In the tree island/marsh habitat, profiles from the VQ-880-G data revealed returns through the vegetated canopy on to bare earth under vegetation, particularly in the wet prairie/marshy areas. The Titan data showed fewer returns through the vegetated canopy and less dense data in bare earth in the wet prairie/marshes. The VQ-880-G data appear to penetrate through the wet prairie/marsh to produce lower ground elevation returns as compared to the Titan, in some areas up to 60 cm lower (**Figure 5**).

Pilot project—conclusions and recommendations

After using conventionally surveyed ground check points to assess the horizontal and vertical accuracy, and measuring the aggregate nominal pulse density, Dewberry found that both sensors greatly exceeded the USGS specifications for QL1 lidar data. However, the ground modelling capabilities of the two sensors exhibited

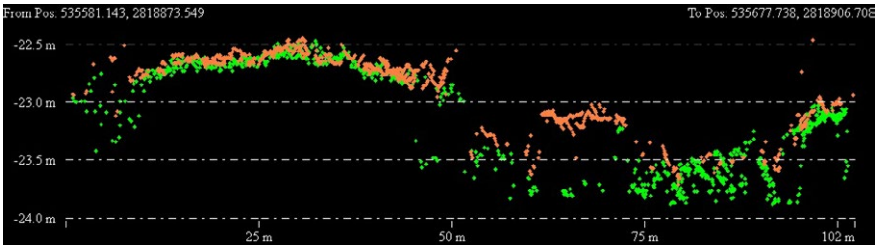

Figure 5: Profile view through a tree island and associated marsh showing VQ-880-G 532 nm data (green points) and Titan 532 nm data (orange points).

subtle differences in tree island and wet prairie/marshes, both critical habitat for Cape Sable seaside sparrow breeding activities.

Based on the above analysis, Dewberry recommended:

- Using a topobathymetric lidar sensor, rather than a topographic-only lidar sensor, for the project,
- Using a sensor with a short-pulse, green (532 nm) laser and a NIR (1064 nm) laser to map the ENP
- Increasing operating altitudes to 600-750 meters above ground level (AGL) would meet the USGS QL1 density, pulse-spacing and vertical accuracy specifications. The higher operating altitude will enable a more cost-effective solution.

The rest of the story

Following the successful pilot project in 2016, Riegl short-pulse duration sensors were used to map 1211 square miles of the eastern ENP (**Figure 2**). This acquisition was accomplished between April and June 2017. The data were delivered to and accepted by USGS/NPS in October 2018. These data are currently available on the US National Map and being used by the ENP to identify critical habitat for Cape Sable seaside sparrows.

Dewberry is currently mapping the western ENP AOI (**Figure 6**). This additional 788-square-mile project, with potential Cape Sable seaside sparrow breeding habitat, was surveyed between March and June 2019, using the VQ-880-G sensor, and is anticipated to be available for distribution in fall 2020, both as part of the US National Map and on the NOAA Digital Coast.

Figure 6: Western Everglades AOI collected with VQ-880-G in spring 2019.

Acknowledgements:
We thank the USGS and the NPS/ENP for their assistance with this project. Ryan Ligon (Dewberry) was instrumental in navigating to ground check points in the Everglades.

For more information, contact Keith Patterson (kpatterson@dewberry.com).

Alvan "Al" Karlin, PhD, CMS-I, GISP is a senior GIS professional at Dewberry. Al has over 20 years of experience managing lidar projects for the State of Florida. With Dewberry, he serves as an in-house consultant on Florida-related lidar and imagery projects, as well as general GIS-related projects. He is an ASPRS Certified Mapping Scientist—Lidar and is a GIS Certification Institute GIS Professional.

Keith Patterson, PMS, GISP is a senior project manager at Dewberry. Keith manages multiple lidar, remote sensing, and image interpretation projects for federal and state clients. As a Florida-licensed Surveyor and Mapper, Keith is responsible for assuring that data meet Florida state standards and ASPRS accuracy specifications. He received his bachelor's degree in geography from the University of South Florida. Keith is also a GIS Certification Institute GIS Professional.

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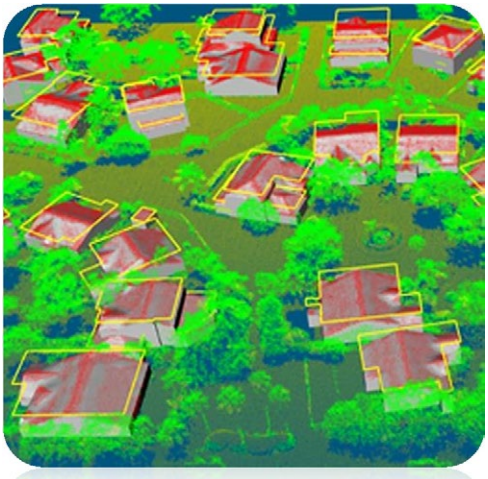
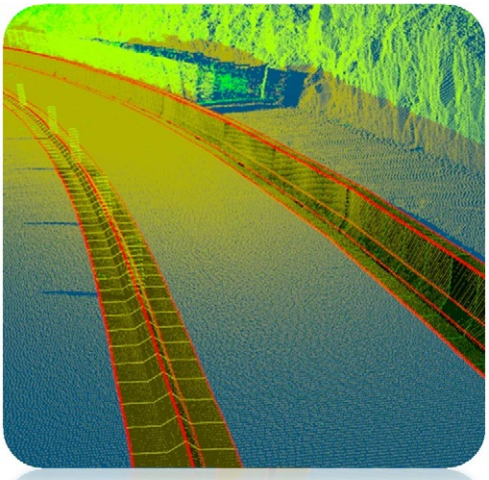
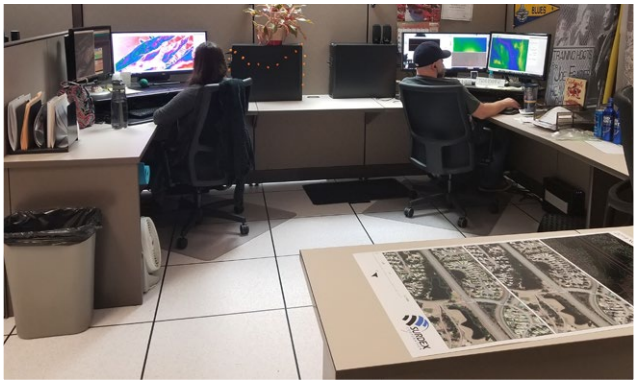




WHEN TO COLLECT NEW LIDAR?

Surdex advises on frequency of collects

Pilot ferrying Surdex aircraft to project site



Production line at Surdex headquarters

The utilization of lidar has evolved dramatically, as technology has paved the way to higher accuracy, increased point density and lower costs. These trends have been driven by the increasing demand for more and higher density elevation data, in response to the needs of both businesses and the public sector. Increased efficiency due to technological advances has further driven down prices.

A public entity will typically conduct a major initial acquisition, such as a county-wide or multi-county project. Once this is completed, the entity may determine whether it needs refreshed lidar data over a specific area based on certain factors, such as:

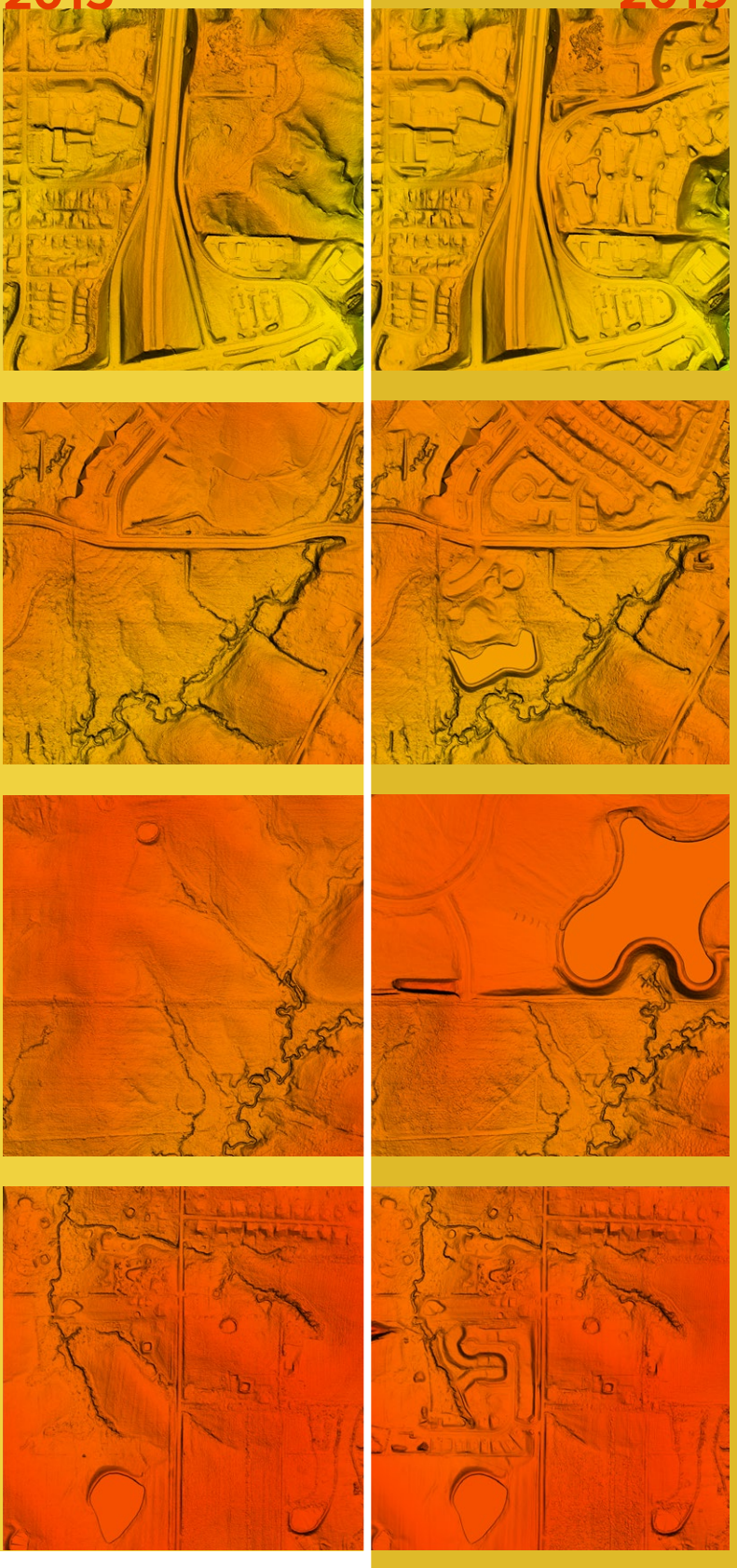
- Changes in terrain
- Population growth and expanding infrastructure
- Industry needs
- State planning
- Federal programs

Such refreshes, indeed, should take place based on these factors, rather than at a specific interval, for example annually. If an entity conducts piecemeal updates, however, they may end up with a "patchwork" of data with variations in point densities and classifications, and

BY BRAD **BARKER**, MICHAEL **GOYMERAC** AND JAMES **WILDER YOUNG**

Dusk shot of one of the Cessna Conquest aircraft in the Surdex fleet

2-foot GSD bare-earth raster pairs, collected 4 years apart



it becomes desirable to have the area completely reflown to establish a fresh, seamless dataset.

Intermediate collection efforts as well as completely new collects are driven by an entity's needs, but tend to conform with the following time frames:

Private sector firms	more than once per year
County/municipal governments	annually
USGS recommendations	every 8 years
State of North Carolina	every 10 years

Teledyne Optech Galaxy lidar sensor installed in a Surdex aircraft

Surdex headquarters and hangar, Chesterfield, Missouri

Changes in terrain

Dramatic changes in terrain make previously acquired lidar inaccurate. Natural disasters, such as flooding, especially of rivers or coastal regions, can create significant changes to the terrain of an affected area. Lidar can be extremely useful for both emergency response and recovery purposes, as well as long-term planning and rebuilding. Following a natural disaster, the distressed community has an immediate need to determine the location and extent of the area of impact. First responders can exploit lidar to estimate the amount of damage and debris, as well as to evaluate roadways and waterways that may be damaged or obstructed. Insurance companies can use it to help assess the extent of damage from virtually any type of disaster, for example floods, tornadoes and earthquakes.

Once the initial emergency is managed, public entities can use lidar data for post-event planning and reconstruction. This may be done with the initial lidar data used for first response, or they may determine that their needs are best met by acquiring additional lidar over an expanded area.

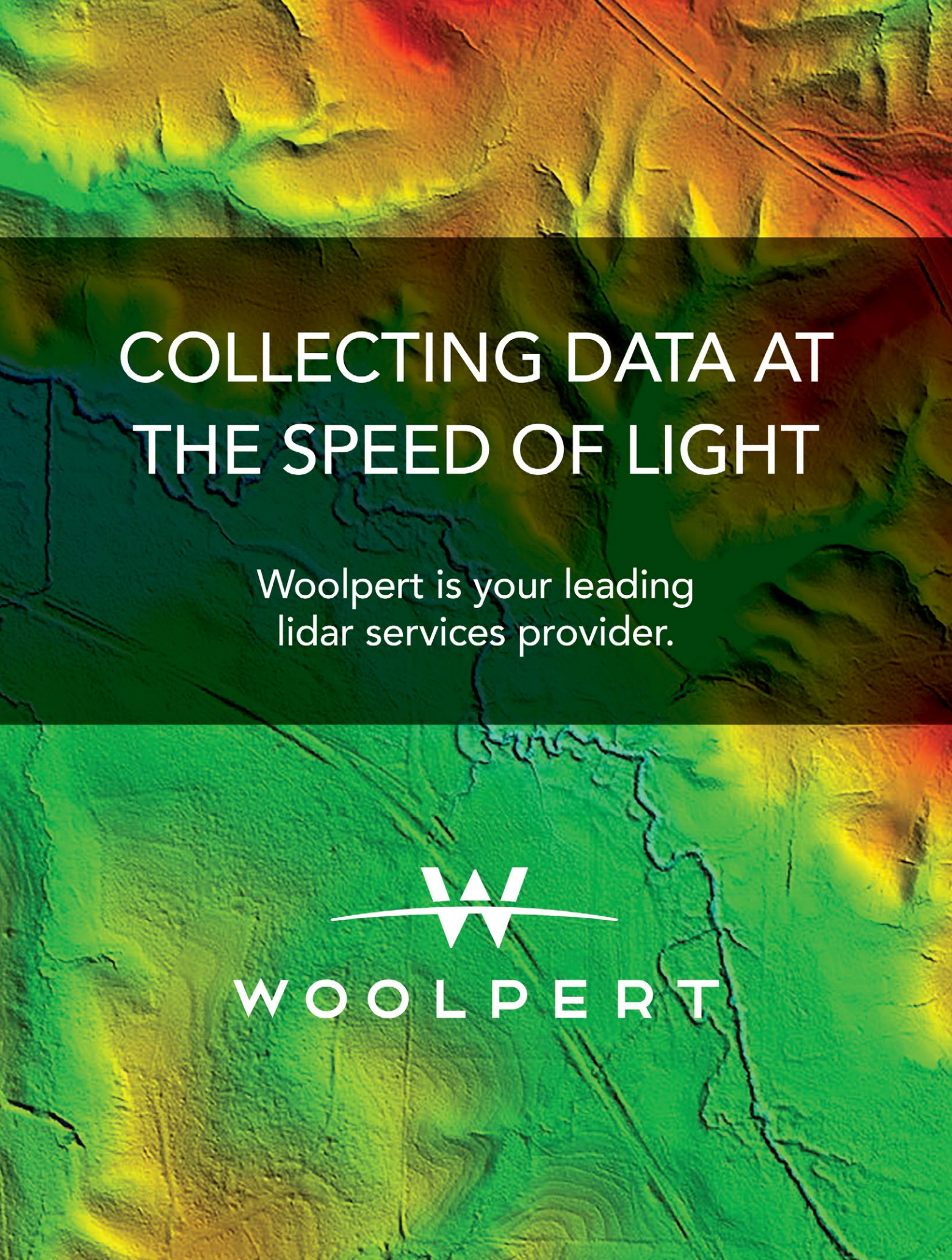
Population growth and expanding infrastructure

Municipalities and counties experiencing sizable growth require up-to-date lidar data for virtually every application—infrastructure expansion, road construction, subdivision planning, etc. These entities necessarily acquire new lidar of undeveloped areas to facilitate development and construction.

Public entities engage construction and engineering firms to develop infrastructure and transportation systems, and the acquisition of lidar is integrated into their building schedule. They often require multiple sets of data, to compare progress or to expand or modify an earlier plan. An entirely new subdivision, for example, will require lidar data not only for constructing new roadways—arterials as well as neighborhood streets—but also to calculate water flow for the planning of water mains, runoff, wastewater and sewage systems. The frequency will depend on the specific need, but often the first collect is immediate.

Industry needs

Many industries have been able to exploit lidar, which has proven to be an efficient method for replacing labor-intensive data collection. The energy sector, for example, has ongoing needs for the safeguarding of transmission lines to ensure uninterrupted flow of energy. One problem affecting the industry is the encroachment of vegetation around power lines.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Previously, power companies have had to spend considerable sums to monitor vegetation, lest it exceeds a certain height or comes within a certain distance of towers and structures. Today, lidar data makes the monitoring of powerline vegetation encroachment much easier. Growth models can be applied to base lidar to assess where and when vegetation should be cut. By evaluating the growth rate, companies can determine the optimal frequency of lidar collects for this purpose. With the advent of airborne lidar, what once took teams of workers thousands of hours can now be accomplished quickly and at much lower cost. The North American Electric Reliability Corporation (NERC) has made recommendations for companies on the use of lidar for this purpose. The energy industry also uses lidar to efficiently map its transmission and distribution infrastructure, again providing a marked improvement over earlier practice.

State planning

Many states have established plans for ongoing collection of lidar data for multiple purposes, with other states poised to follow. Around 1998, North Carolina collected lidar data at a spacing of 2-5 m for the entire state, based on river basins, for floodplain mapping and emergency management. This project was the best-known 3D project at the time. Most states emulating the North Carolina project collected lidar data at a post-spacing of 1.4 m. In 2014, North Carolina increased the density to 2-4 points per square meter, with other states following suit. Since then, many states have acquired complete lidar coverage, and some have started repeat collections at higher point densities and accuracies due to their needs and a reduction in pricing.

Federal programs

The origins of the Federal Government's involvement in lidar began with floodplain mapping and geological applications. From rather limited beginnings, the Federal Government has done much to support and encourage the increased acquisition of lidar data. Agencies such as FEMA and USGS have long supported the use and expansion of lidar. Before lidar, the vertical accuracy of FEMA's Flood Insurance Rate Maps was 4 feet; when this data was replaced with lidar, the vertical accuracy improved to 15 cm (6"), making these maps significantly better and enabling much more reliable analysis of floodplains and the establishment and declaration of an area as a floodplain.

In 1998, USGS flew a 7.5-minute quadrangle with lidar, and ever since has been a very strong supporter. Countless projects have been carried out to provide lidar for USGS and FEMA, and countless more have used these public-domain sources as input. USGS did an extensive study on the frequency and timing of lidar collection. The resulting program from this study is the 3D Elevation Program (3DEP): https://www.usgs.gov/core-science-systems/ngp/3dep. The essence of the program is that all lidar data should ideally be refreshed every eight years. The objective of 3DEP is to involve as many interested parties as possible, combining resources to provide a publicly available, quality product for the best price. USGS encourages participation from partners and users at state, county and regional levels. There are minimum requirements and specifications for projects within this program, which is open to bids from any interested party.

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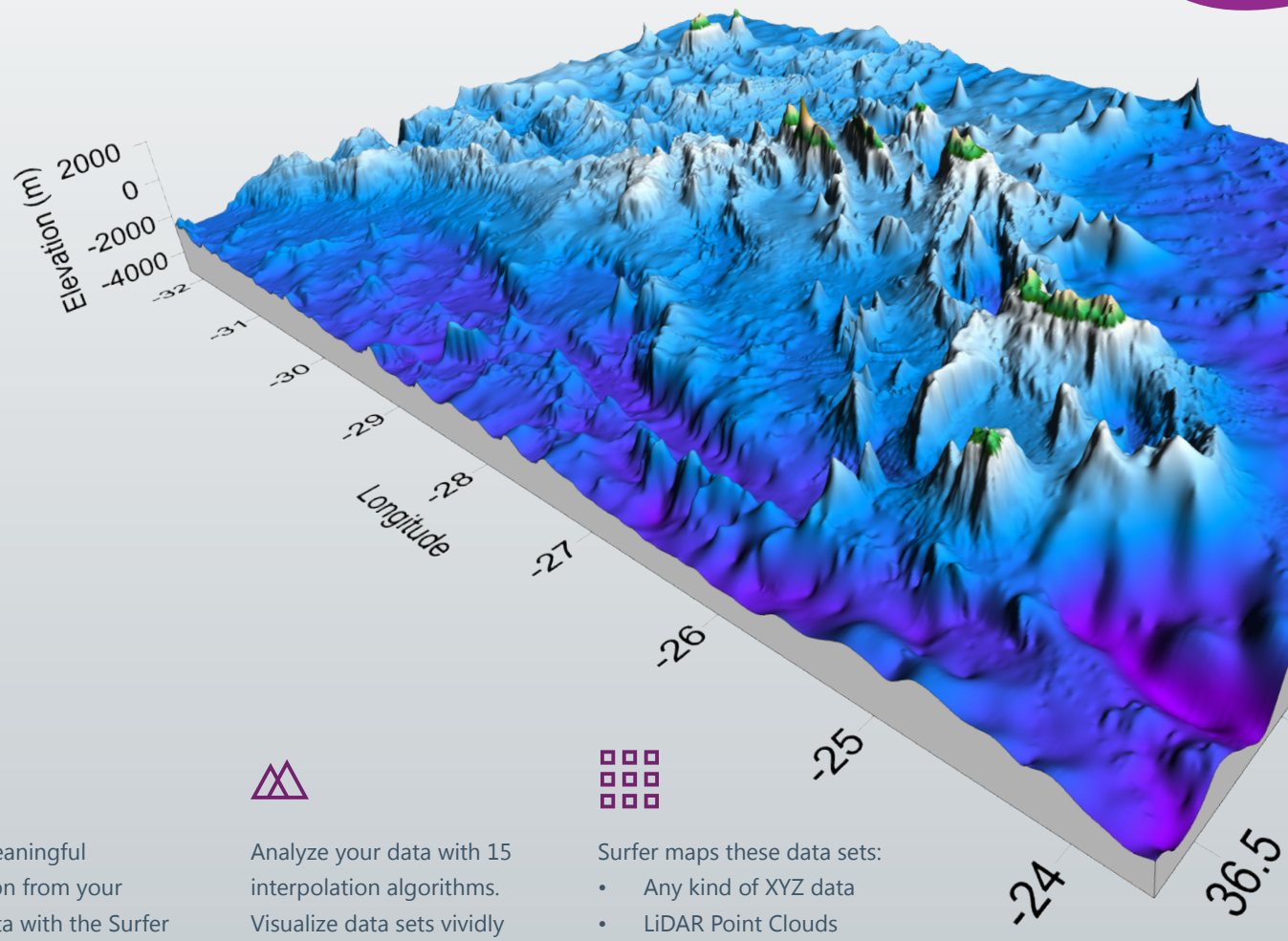

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Benefits of collective purchasing

Public entities have found that, even if not using 3DEP, multiple entities realize cost efficiencies by pooling resources and bundling projects. This can affect an entity's decision about the frequency of collection. If a county is planning a lidar project for two years from now, but the surrounding counties are teaming up for a project next year, there may be sufficient incentive to refresh its data sooner.

Conclusion

Lidar has grown in importance and has proven its value over the years, demonstrating expanding uses and applications. Users have seen its density and accuracy increase while simultaneously seeing their costs decrease. With the increased utility of lidar and cost efficiencies due to technological improvements, federal assistance, and cooperative partnerships, entities have a newfound flexibility to increase the frequency of their lidar acquisition. Collectively, entities can enjoy a higher refresh rate of more precise—and therefore more useful—data for a lower cost, providing them with a significant return on their investment.

Brad Barker is Surdex's director of 3D mapping. He has over 22 years of professional experience and received a BS in cartography and map technology from Southwest Missouri State University. He supervises and coordinates the production phases of compilation, lidar, and finishing. linkedin.com/in/brad-barker-4365894a

Michael Goymerac, CMS-L is Surdex's lidar product leader. He has over 14 years of professional experience, received a BS in geography, with a minor in geology, from Northwest Missouri State University, and is an ASPRS Certified Mapping Scientist—Lidar. He is responsible for all phases of lidar processing and ancillary production. linkedin.com/in/michael-goymerac-cms-30484a45

James Wilder Young (Jamie), CP, CMS-L, GISP is currently executive vice president of technology for Pointerra, headquartered in Perth, Australia. He currently supports all aspects of lidar technology as it relates to software as a service (SaaS) and provides innovation in analytics. His experience includes all aspects of lidar including sensor development, applications development, data acquisition, data processing and project management. He is author of *LiDAR for Dummies*. He graduated from the University of Colorado.

Further information is available from Surdex Corporation, www.surdex.com.


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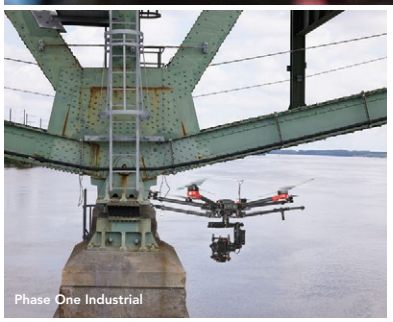
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The Kreekrak locks in the Scheldt-Rhine Canal, which runs from Antwerp to the Volkerak and is part of the Scheldt-Rhine connection, the shipping route between Antwerp and Rotterdam.

Repeated Imaging Success in Schiphol

In 2018, Schiphol Airport in The Netherlands recorded 499,444 commercial air flight movements, an average of about 1,350 take offs and landings per day. That quantity makes the airport an impressive third in busiest airports in Europe for passenger volumes, but it's not a great statistic if you're a geodata provider that needs to conduct an airborne survey near that crowded air space.

Geospatial services company BSF Swissphoto knows a thing or two about that kind of air-traffic challenge. Since 2016, it has had to learn how to be nimble and flexible in order to successfully deliver on an annual aerial photo campaign north of the airport.

BY MARY JO **WAGNER**

"Roughly 85 planes are landing or taking off at Schiphol every hour, so flight control is incredibly strict," says Sandra Beckmann, a project leader with BSF Swissphoto's German office in Schönefeld. "When we are given a flight window, we have to be ready to go at a moment's notice and we can't afford any mistakes in collecting our photos because it puts meeting our delivery deadline at risk. It's an added level of complexity in a project that's already challenging."

The famous Molen van Piet round stone flour mill in the Dutch city of Alkmaar. Located in North Holland, Alkmaar is a popular tourist destination well known for its traditional cheese market.

Indeed, in addition to working around potential weather delays and air traffic restrictions, the company has also had to meet unforgiving technical specifications and deadlines. They've had to produce homogenous, seamless orthomosaics with a ground sample distance (GSD) of 4 cm for a 900-square-kilometer area of interest (AOI)—about the size of Madrid—in 11 weeks.

However, Beckmann and her team have successfully shown that a smart flight plan and robust and efficient photogrammetry software are the right combination to navigate and land a complicated aerial survey and secure a route to repeat flights in the future.

A routine exercise in coordination

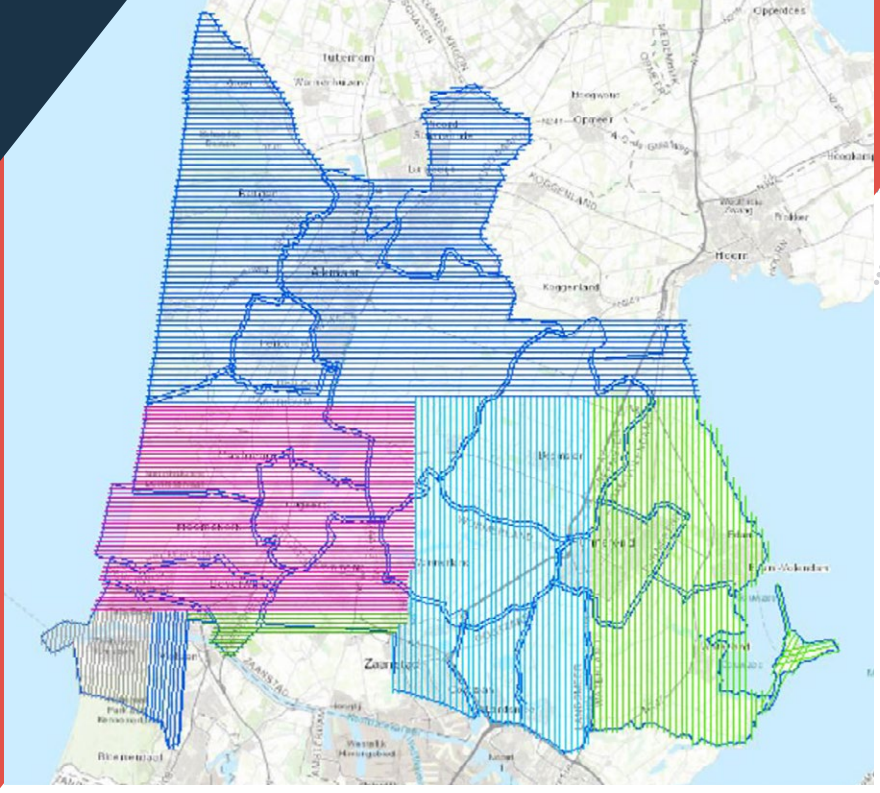
Flying the skies and photographing the ground underneath their wings has been at BSF Swissphoto's core since it was first established in Switzerland in 1930. The company took on its first aerial survey and photogrammetry flight in 1960 and steadily grew its business by offering multi-sensor solutions with millimeter accuracy.

With a record for successfully delivering on surveying projects near Schiphol and other challenging areas around Europe, BSF Swissphoto was in a strong position to respond to the aerial photo needs of the Information & Coordination Centre (ICC) of the Schiphol Region. The ICC represents about 60 government-affiliated organizations, including 47 municipalities, and works to coordinate and provide access to up-to-date aerial photographs and other remote sensing products on a routine basis. Since 2009, it has issued tenders to capture high-resolution photos of the 2800-sq-km Region that extends from Alkmaar in the north, Almere in the east and Zoetermeer in the south. Participating members use the detailed photos to update their large-scale topographic maps, for urban and environmental planning, for security and for monitoring land-use changes.

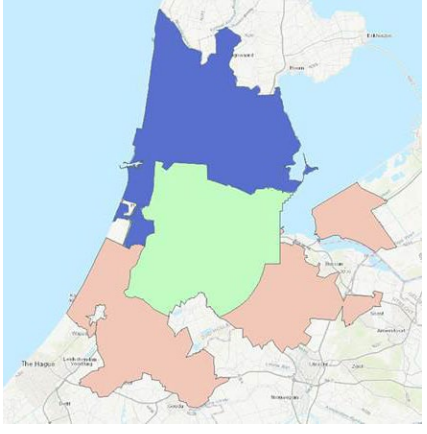
Depending on the number of ICC participants, the program's total AOI can change year on year, but the delivery

An industrial area in the town of Velsen-Noord, about 10 kilometers north of Haarlem.

The shore along the seaside resort town of Bergen aan Zee, about 9 kilometers west of Alkmaar.



A graphic of BSF Swissphoto's AOI area including the municipalities. The lines indicate the flight plan.



A map of the complete ICC area split into three parts. The blue parcel is BSF Swissphoto's AOI.

requirements are always the same: orthomosaics with a ground sample distance (GSD) of 4cm or less.

In 2016, BSF Swissphoto received a two-year contract to survey one of three AOIs under the ICC's Vertical Aerial Photo program. Proving its capabilities, it was then awarded a subsequent contract for the same 900-sq-km area for 2019 and 2020.

"We are skilled in developing well-crafted and realistic flight plans that not only enable us to be efficient in the air but also in processing the stacks of images we acquire," says Beckmann. "Equally important is our ability to meet the exacting technical requirements. With Trimble's Inpho® image processing software we have the tools we need to meet the orthophoto precision and the delivery timeline the project demands."

Collecting the aerial component

For the 2019 campaign, BSF Swissphoto's AOI included 17 ICC municipal territories in the northern part of Schiphol, each of which required its own seamless orthomosaic. In addition to the very high resolution specifications, the orthomosaic had to be precisely color-balanced—no dark shadows or excessively bright spots—geometrically accurate, completely clear with distinct contrast, and aesthetically pleasing.

The aerial campaign began in February in order to acquire images of bare trees and to ensure they capture as much ground detail as possible.

Considering the restrictive and complicated air traffic regulations, BSF Swissphoto split the whole AOI into seven sub-areas, delineating smaller fly zones near the airport and larger sections further north. The smaller sections were carefully chosen because the team knew they'd collect a significant volume of photos and they wanted to ensure the orthophoto production would go as smoothly and efficiently as possible.

To coordinate with the flight plan and to achieve consistently high accuracy over such a wide area, BSF Swissphoto used a base station, GNSS receiver and differential GPS (DGPS) technology to establish control for each sub-area, and they set out a network of ground control points (GCPs).

For the GCPs, teams used a combination of colored, physical targets and painted markers on hard surfaces at set intervals within each sub zone and measured the center points of each with a GNSS receiver. They set GCPs in groups of two, each placed close together for

A view of the Stad van de Zon housing and building project in Heerhugowaard, The Netherlands. Heerhugowaard is one of the 17 municipalities included in BSF Swissphoto's AOI.

point redundancy, and laid out a total of 164 GCPs with a horizontal accuracy of better than 3 cm.

After setting control, BSF Swissphoto dispatched their flight crew to collect aerial imagery. Flying at altitudes of both 335 meters (1,100 feet) and 427 m (1,400 ft) at speeds between 120 to 155 km/h, they covered the entire AOI in 30 hours over six days. They flew 261 flight paths and collected 30,000 images with their large-format digital camera. The images had a 60 percent endlap and the average sidelap between the flying strips was about 30 percent.

"Flying at such low altitudes is risky because the slightest deviation—like movement from a sudden gust of wind—can impact our defined overlap or clarity in a photo," says Beckmann. "We were fortunate to have good weather for the flights."

Orchestrating the orthophotos

After downloading and processing the aerial images and aircraft trajectory data, Beckmann and colleagues imported them together with the GCPs into the MATCH-AT georeferencing module of Inpho to automatically triangulate the images. The software processed the 30,000 images in batches and automatically pinpointed 254,000 common features or tie points (TPs) with multiple connections across the images. The precisely surveyed GCPs were measured in MATCH-AT, and in a second quality control step, the team used MATCH-AT's Stereo module to manually verify and measure all the GCPs in stereo. After that the imagery was precisely oriented automatically.

"The automatic triangulation and tie-point identification capabilities in Inpho are very good and give us the essential foundation for creating precise orthophotos and orthomosaics," says Beckmann. "You can't build an accurate result from an inaccurate base."

After the final triangulation was done, the team downloaded an existing LiDAR-based digital terrain model (DTM) of the entire AOI and analyzed it for land-cover changes that needed to be corrected or updated. The DTM was then integrated into the Inpho software.

With the Inpho OrthoMaster module, the software used the DTM to automatically orthorectify the individual images with a ground resolution of 4 cm. Switching to Inpho OrthoVista,

Schiphol Airport recorded 499,444 commercial air flight movements in 2018, making it the third busiest airport in Europe for passenger volumes.

the photogrammetry tool for creating seamless orthomosaics, each orthophoto was stitched together to create a 2D orthomosaic of the entire AOI. Experienced BSF Swissphoto operators then performed quality control checks on each orthomosaic and flagged any potential issues such as incorrect seam lines. They could then use editing tools such as the OrthoVista Seam Edit tool, in coordination with ancillary data like building outlines, to manually check the seam lines and ensure they didn't intersect buildings or cross objects like bridges that would be distorted in the mosaic. Any imperfections were fixed to create seamless, color-balanced and geometrically correct orthomosaics of the 900-sq-km AOI.

"We've been using Inpho technology since 2005 and so far, we haven't found any solution better than OrthoMaster and OrthoVista for creating ortho products," says Beckmann.

After completing all the orthomosaics, BSF Swissphoto personnel then prepared the customized deliverables. Per the ICC's requirements, they not only finalized all 17 orthomosaics, but for each city, they selected all the ortho tiles belonging to each city's territory and formatted each as a TIFF file, enabling them to provide both the seamless mosaic and the corresponding individual tiles to each customer. Within 11 weeks of completing the aerial survey, each of the ICC cities had received their up-to-date orthomosaic for 2019.

"We wouldn't have been able to process and transform 30,000 photos into real-world, color-balanced and seamless 2D orthomosaics in 11 short weeks without the automation and accuracy of the Inpho software and a strong team," says Beckmann. "The clarity and detail these orthomosaics provide will be a valuable geospatial dataset for ICC participants."

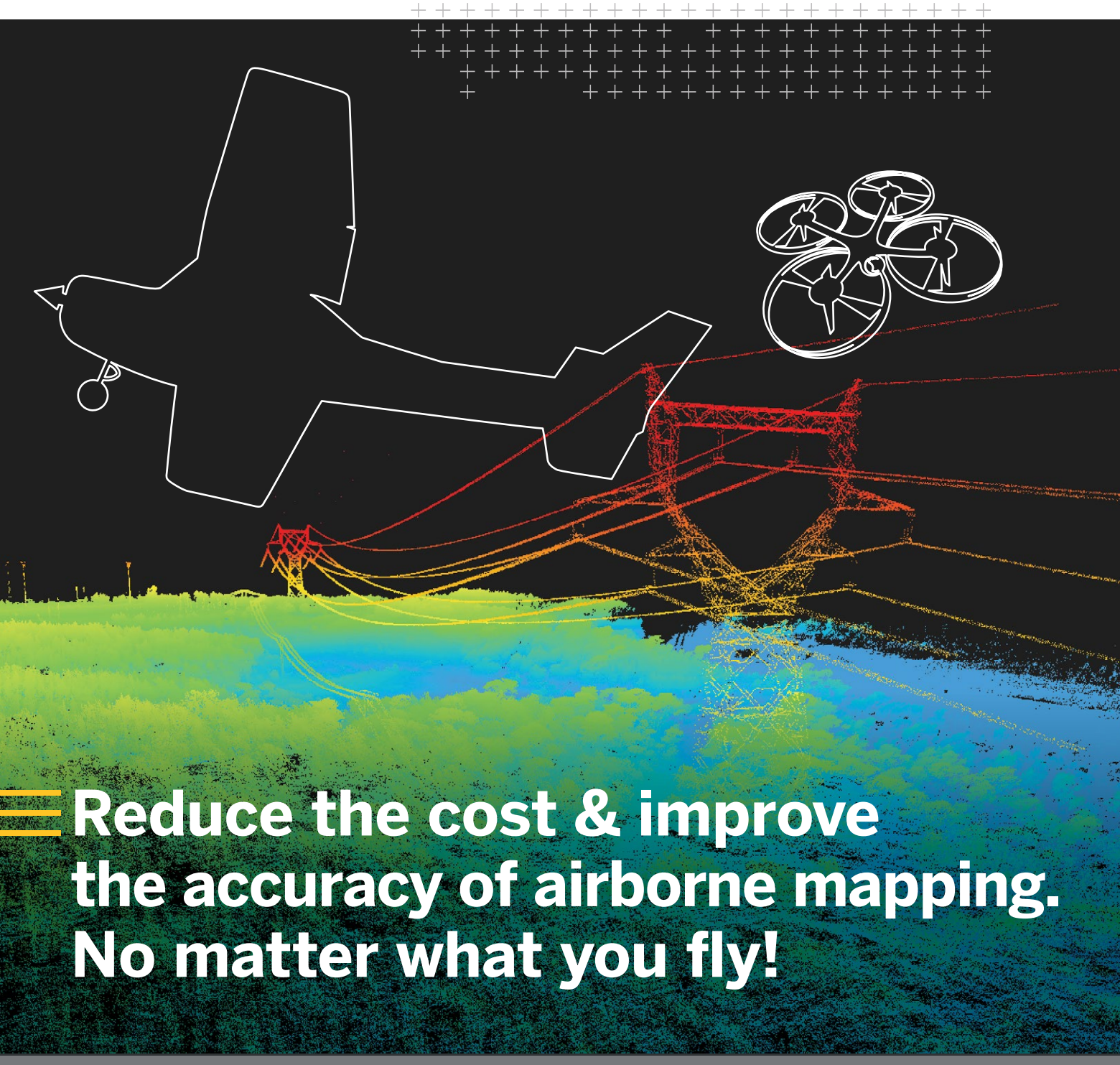
A shot of Amsterdam taken in flight.

Indeed, with the routine procurement of airborne imagery, the ICC members are living proof of the benefits of one of the organization's mottos: "Acquire aerial photos once, use them multiple times."

"The need for up-to-date, fit for purpose geo-information has steadily grown in recent years," says Leon Hendriks, the ICC's program manager. "Historically, this data hasn't been easy to obtain for individual organizations in the Schiphol Region because of their proximity to the airport and access restrictions. Since 2009, the ICC has been able to coordinate one aerial campaign to serve multiple users within the Region. With these brilliant, accurate and data-rich orthophotos our members have the spatial intelligence to better plan for city and rural development, monitor their landscapes, respond to permitting requests and appeals and communicate to the public. It's been a very successful program and one we plan to continue for the foreseeable future."

That future has already begun. BSF Swissphoto took to the skies in mid-February to initiate the 2020 Vertical Aerial Photo campaign, and will again be producing seamless orthomosaics for the participating ICC members in its AOI. Anchored by its smart approach to flying in combination with its image processing software, BSF Swissphoto may have the tailwind to land more airborne surveys in the future. ■

Mary Jo Wagner is a freelance writer who has covered the geospatial industry for 25 years. Email: *mj_wagner@shaw.ca*.



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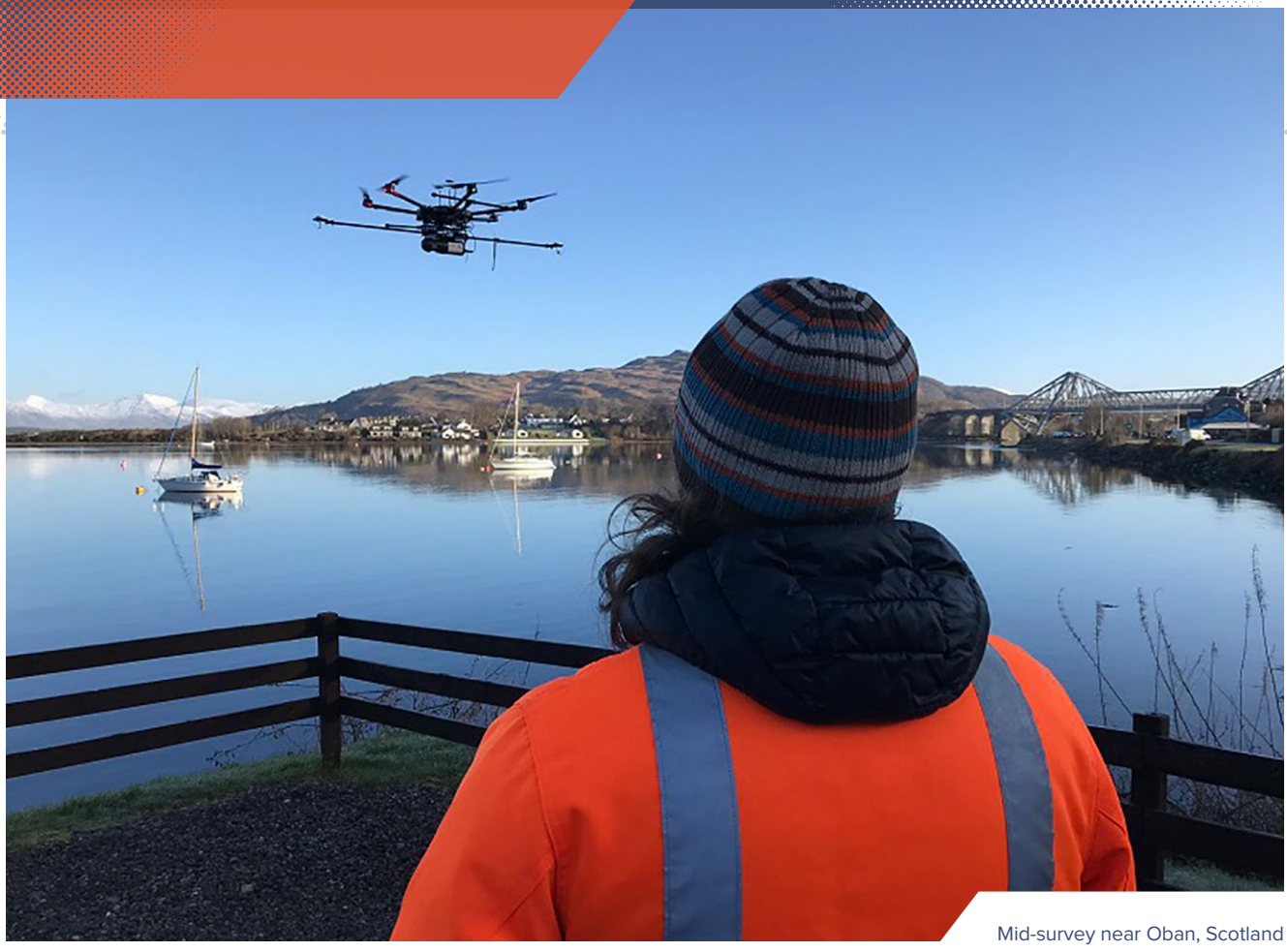

Mid-survey near Oban, Scotland

The Real Advantages of UAV-lidar

Routescene asks its customer **FlyThru** about lidar experiences

BY JASON ROGERS

Routescene's Marketing Manager, Jason Rogers, interviewed Michael May and Ben Bishop from FlyThru[1], a Routescene[2] customer, whilst on location surveying a proposed cycle route between Connel and Dunbeg in the Scottish Highlands. On a cold and beautiful morning in March 2020 (prior to the coronavirus lockdown), we discussed how their business had benefited from UAV-lidar by investing in a Routescene UAV-lidar system.

Routescene: How did FlyThru start?
FlyThru: Flythru was started six years ago by two directors. I (Michael) brought business acumen and experience flying light aircraft and helicopters. My business

1 www.flythru.co.uk
2 www.routescene.com

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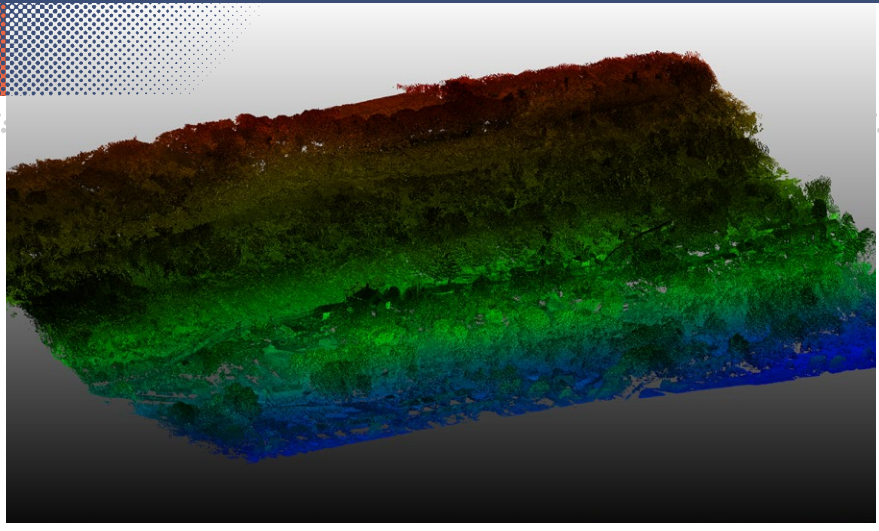


Point cloud displaying the dense vegetation coverage at the landslide site at Ystalyfera, Wales

partner Ben had flown and manufactured both fixed-wing and multi-rotor drones for a number of years. We met at a Civil Aviation Authority training course, hit it off immediately and realised we were better operating together than separately. So we built the business up from there. The focus of FlyThru, based in the UK, is the provision of UAV services to obtain aerial data.

Airborne lidar has been accepted by the surveying community for more than a decade. With the emergence of UAVs, the possibility of acquiring aerial data in a more accessible way was an exciting one. Drones have the ability to fly much lower and slower than a helicopter or plane, with the benefit that the resultant point-cloud data has vastly greater detail. We saw UAV-lidar as a growing business opportunity.

Routescene: What technology did you use before you started working with lidar?
FlyThru: Most of our projects used UAV-photogrammetry. However this is unable to provide accurate ground data on sites where there is vegetation. The camera photographs the first thing that it sees, which is the tree canopy, so you are unable to create an elevation model that shows the floor of a wooded or vegetated area. The real magic of lidar is the ability to penetrate through vegetation to reach the ground, capture the ground surface accurately and produce a valuable Digital Elevation Model (DEM).

Routescene: How did you discover UAV-lidar?
FlyThru: We discovered UAV-lidar by accident really. We were working on a forensic archaeology instruction and the customer was using the Environment Agency's airborne lidar equipment to help create site maps. The aim of the project was to find a clandestine burial site and lidar was perfect for this. We searched 'UAV-lidar' online and up popped "Routescene", which provided such systems. We immediately jumped on a plane to Edinburgh in Scotland for a meeting to learn more. It all went from there and the rest is history.

Routescene: For you, in which applications does UAV-lidar stand out?
FlyThru: Nine times out of ten the purpose of our UAV-lidar projects is to produce a DEM. Typically we are working in locations where that is difficult or impossible to achieve using traditional survey methods and airborne lidar from fixed-wing aircraft or helicopters is cost-prohibitive. This is where UAV-lidar comes into its own—it's much cheaper, easier and quicker to deploy.

We have used UAV-lidar across a wide array of instructions from monitoring the habitats of beavers in the Scottish Highlands, to assisting planners assessing heavily vegetated areas for development, to investigating clandestine burials and other forensic cases.

Routescene: Who are your customers?
FlyThru: Our clients vary from planning consultants who want to assess sites for potential development, to forensic archaeologists, to landscape maintenance and preservation such as Scottish Natural Heritage. We use UAV-lidar because our clients are asking for it—they want to see quality, accurate data, which is impossible to achieve any other way.

Routescene: What obstacles did you face when first working with UAV-lidar?
FlyThru: It's been a learning curve. It's easier to work with photogrammetry as everyone's used to identifying objects in photographs. Interpreting what you see in a 3D point cloud is very different. When we first started we used to view a point cloud alongside a photograph so we could identify the features and objects easily. With help from the Routescene team we managed very quickly to get up to speed. We have the experience now to "see in 3D" and have learned how to interpret what we are viewing in the point cloud.

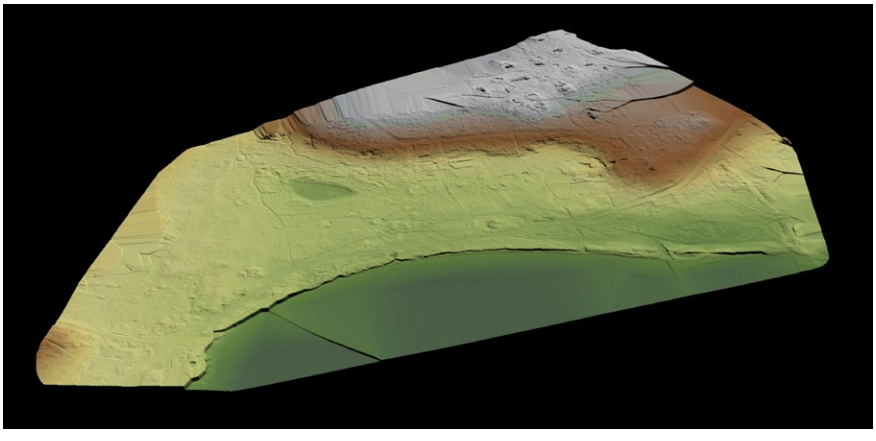
Routescene: What are you currently working on?
FlyThru: We are assisting a Council in the Scottish Highlands on a proposed cycle route between Connel and Dunbeg. The proposed route is covered by heavy vegetation, some parts cross over water and some are at the shoreline. It would have taken weeks to survey conventionally,

some parts being almost impossible to access. So we used the Routescene system to undertake a complete survey in a handful of drone flights. The Council will use the final DEM output to assess the best course for the new cycle route.

Routescene: What are your most memorable projects?
FlyThru: A repeat survey undertaken at frequent intervals of a landslip in Ystalyfera in Wales is certainly memorable. The aim was to identify the rate and scale of ground movement across the landslide area. Local residents were moved from properties that were at risk from future landslips. We believe this critical data led to peoples' lives being saved.

A very different and equally dramatic project was to visualise a Second World War German SS concentration camp on the Island of Alderney in the Channel Islands, UK, the only camp on British soil. Combining the UAV-lidar data with photogrammetry and radar enabled us to capture unique data never seen before, which led the archaeologists to uncover new gravesites at the camp. It was a poignant project whilst thoroughly interesting at the same time. It was a great feeling to capture such powerful information for future generations to ensure it is never forgotten.

Alderney in the Channel Islands, UK—site of a UAV-lidar survey to visualise a WWII German concentration camp



DEM of the site of the concentration camp which uncovered new gravesites

Routescene: How do you go about setting expectations with your clients?
FlyThru: The two key points to discuss are accuracy and the quantity of data they will receive. Often the clients think they want the highest resolution imagery and point cloud you can give them. But they don't understand how much data the lidar system actually collects—millions upon millions of points! On a couple of instructions the clients simply didn't have a powerful enough PC to open the data file—there's that much information. We have to manage that expectation at the outset.

Typically we offer clients a DEM with a 25 cm grid resolution. In terms of accuracy we achieve <45mm in almost all projects. Again, setting that expectation is important—inaccuracies are obviously caused by the UAV in motion. It cannot be compared to a static terrestrial laser scan from a fixed ground point.

Through light vegetation we often achieve an impressive 400 points per square meter (ppsm), which compares very favourably against the 3,4,5 ppsm from airborne lidar.

Routescene: Talk us through how you tackle a new UAV survey project.
FlyThru: Safety always comes first and

Full equipment set-up ready for survey of proposed cycle route near Oban, Scotland

we consider, "Can we fly the site safely?" If the answer is yes, then we move to pre-survey preparation. Typically, we run an internet search looking at maps available online and use that information to produce an initial flight plan. A site visit, either beforehand or on the day of the survey, enables us to modify flight plans and routes, depending on what we find on site. Establishing ground control points (GCPs) is essential. We use the Routescene Ground Station, part of its UAV-lidar system, to survey in known co-ordinates to sub-centimeter accuracy. The Ground Station ensures RTK corrections are transmitted to the LidarPod and quality assurance and status information is transmitted to QA Monitor, the real-time in-flight data monitoring software. With GCPs established we can relate the data and the resulting model to the real world.

We then start to set up the equipment ready for the survey itself. First, we intialize the UAV and the Ground Station, then we place the GNSS antenna over one of the known GCPs to provide the reference for the RTK positioning. Next, we assemble the LidarPod and mount it underneath the UAV. We power everything up and perform a series of checks to ensure everything is functioning as it should. We are then ready to fly and collect data. During the flight we constantly review the data using QA Monitor, so we have the confidence we are collecting the required data. At the end of the mission we download the data into LidarViewer to check it there and then on-site, with this quick preview we can be assured it looks correct before we leave the site.

LidarViewer is a really good post-processing software package. It enables us very quickly to thin out the unnecessary data, remove any noise and within a matter of minutes we have a "tidy" point cloud ready for further processing.

Routescene: What would you say to someone thinking of using UAV-lidar in their business?

FlyThru: Having a good understanding of how the whole system works is vital to ensure you get the best from the system. One of the most important factors is being able to deal with the data processing. The LidarPod makes it easy to capture data, turning that into a useful product for the client is the challenge. Ensuring you have GIS/lidar data analytical skills is key, so you can turn a raw point cloud into a final output such as a 1m resolution gridded DEM. LidarViewer helps to make post-processing of such large volumes of data easier.

UAV-lidar adds another dimension to our drone service business. We can fly over and accurately map areas that are either almost impossible to reach or dangerous to walk through, such as landslips. It enables us to achieve accurate DEMs that would be unachievable otherwise.

Our UAV-lidar system is now used 2-3 times a week. It is in almost constant use The surveying world has accepted UAV-lidar and its outputs and we are receiving more and more instructions.

Routescene: How do you find the Routescene UAV-lidar system?

FlyThru: The LidarPod has been great for us because of its powerful vegetation penetration capability. 90% of the work we receive requires data to be acquired in difficult-to-reach, heavily vegetated areas. We were surprised by the high ppsm numbers we were achieving through dense vegetation, not just in winter, but in summer. Providing clients with high resolution DEMs as a result of achieving 400-500 ppsm, when previously they had had to work with DEMs derived from point clouds offering only 2-3 ppsm, has allowed us to develop our business with those clients.

Routescene: How have you found working with Routescene?

FlyThru: The advantage of working with Routescene over the last 3+

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BY DR. A. STEWART WALKER

With Ron Behrendt of RIEGL USA

Lidar and GIS grow closer together

Riegl RiMAP Add-In smooths the data flow from LiDAR scanner to Esri's ArcGIS Platform

Lidar is a major source of geographic information, yet its voluminous data sets and their characteristics, which are different from those of image or vector data, historically have made it less accessible to GIS users. Esri and *RIEGL* are working together to improve the situation, helped by Ron Behrendt, managing director of Behron LLC, a geospatial consultancy based in Whitefish, Montana. *LIDAR Magazine* asked Ron to say more about his work.

LM (Managing Editor, Dr. Stewart Walker): We have approached you today to discuss your work for *RIEGL* and Esri. Please tell us how this began.

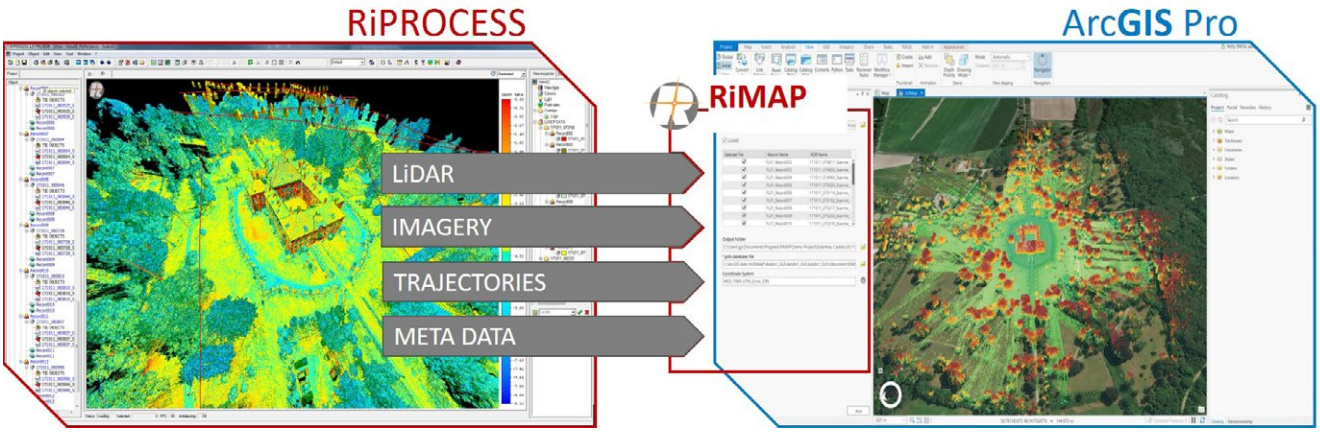
RB: I focus on providing clients who wish to utilize remote sensing technologies (imagery, lidar, radar, etc.) as information sources managed and analyzed in a GIS. I provided consulting services to Esri from 2011 to 2016, assisting with its new ArcGIS lidar capabilities and working with Esri's users to help them better understand and benefit from this new functionality. During this effort, it became apparent that an improved customer interface between lidar sensors and the ArcGIS Platform would provide numerous benefits to the end user, including higher efficiencies, better data management, and the ability to leverage Esri's new 3D Web GIS capabilities. *RIEGL* was quick to see the potential benefits for its customer base and in 2017 brought me in to help evaluate the opportunity to integrate lidar sensors more closely with GIS, explore technical options, and help develop prototype workflows that could be used for market research.

LM: Please tell us about the software you are developing and the difference it will make to users of *RIEGL* sensors and/or Esri software.

RB: *RIEGL* is currently developing the RiMAP software product, which is designed to smoothly transfer the content of a *RIEGL* scan project to Esri's ArcGIS Pro so the data can be fully utilized for both desktop and web GIS applications. The beauty of this is that most of these projects have lidar and imagery. In terms of point clouds, the *RIEGL* RDB (*RIEGL* Data Base) data, which is created and populated as a result of performing post-capture processing with *RIEGL*'s RiPROCESS software, is brought into ArcGIS Pro for immediate analytics. Co-registered Imagery is made available as mosaic datasets or the new oriented imagery type as well as trajectories and some valuable metadata. One of the benefits of RiMAP and its data capabilities is that it has created the ability to leverage all ArcGIS functionality for storing and managing the data, a task which has become increasingly important as users are capturing more and more lidar including airborne (manned and unmanned) and mobile.

LM: What stage has the software reached? Is it ready to be launched, or in alpha or beta?

RB: The RiMAP software is currently in development with internal testing scheduled to begin Q1 2020. An extensive beta test program will follow, allowing the software to be well exercised before it is released to the general public, with the end goal of a high-quality offering that



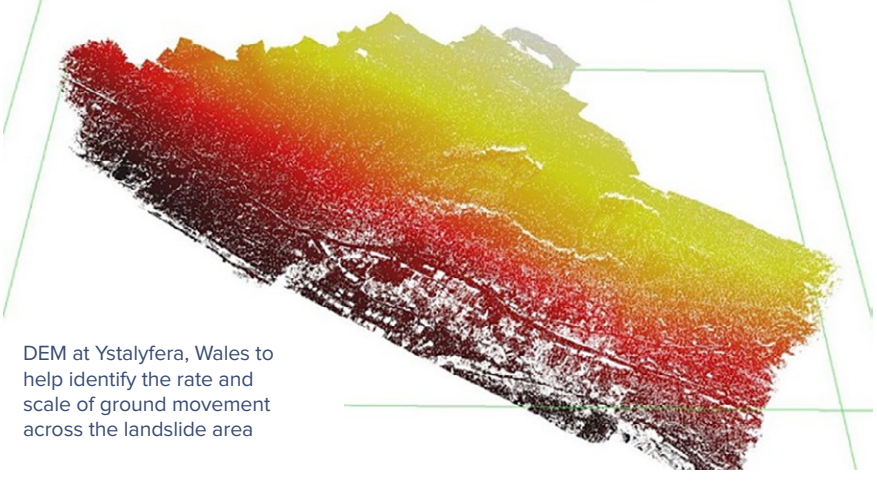
is simple to use. There is no firm date for the first release of RiMAP, but an announcement will be made when it is available for public use.

LM: How will the new software be monetized?
RB: *RIEGL*, with its strategic and long-standing partnership with Esri, will utilize the Esri Marketplace to distribute the RiMAP software. Created as an add-in to ArcGIS Pro, *RIEGL*'s RiMAP software will expand ArcGIS Pro's capabilities and enable the functionality mentioned above. The first release of RiMAP will be targeted to owners and operators of *RIEGL* lidar systems and initially will be offered to them at no cost.

LM: What is the next stage in the process?
RB: We are exploring additional opportunities to expand the initial RiMAP offering and planning to announce RiMAP 2.0 during the second half of 2020. The architecture we are developing creates numerous opportunities to leverage many of Esri's newest 3D technologies in combination with the highly accurate data captured by *RIEGL* lidar systems. We envision that RiMAP will grow and become an integral part of the workflow for professionals using the combination of *RIEGL* lidar and Esri ArcGIS.

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.

Routescene, *continued from page 44*
years was that both we and they were new and upcoming businesses which complemented each other. Routescene have been fantastic throughout this journey. If we have problems in the field they have helped us immediately on the phone. Usually that has solved the problems. If we do have any hardware or software problems we have been in direct contact with them and they have fixed it as quickly as possible.



DEM at Ystalyfera, Wales to help identify the rate and scale of ground movement across the landslide area

Routescene: What difference has the Routescene UAV-lidar system made to your business?
FlyThru: Lidar has given us another string to our bow. We started with photogrammetry along with photographic imaging from drones. UAV-lidar is another mapping technique that complements photogrammetry and in some cases actually replaces it. It has probably grown our business by 50%.

The Routescene UAV-lidar system has been phenomenal. It's really opened up a unique revenue stream for us. It's enabled us to capture data that's impossible to capture in any other way. That's opened up doors with unique clients and also unique applications, which sets us apart from the rest of the field.

Jason Rogers is Marketing Manager at Routescene. His responsibility is to build the Routescene brand and grow awareness of the advantages of the Routescene lidar system. With over 20 years' marketing experience, Jason brings a wide range of skills to the role. He has previously worked in the diagnostic imaging and automotive sectors.

***Graham,** continued from page 48*

As a simple example, let's look at a project (**Figure 1**) we collected of a rugged bit of terrain in the north Alabama Appalachians. The site, the Rock Farm, belongs to David Glenn, our Director of Enterprise Solutions. We flew this site to test mission planning in steep terrain. As you can see in **Figure 1**, our swath spacing is a bit larger than we would like but density was sufficient everywhere for excellent modeling.

To simulate collecting this project using conventional survey techniques, I performed the following steps:

- Classified ground using our True View Evo automatic ground classification (2 minutes for the entire project)
- Gridded the data into 50 m × 50 m cells
- Randomly sampled one ground point from each cell, moving it to class 23
- Created a Triangulated Irregular Network (TIN) from this sparse class 23 data
- Draped lines over the TIN
- Compared these draped lines to the original ground class

This process will provide us a measure of the degradation of fidelity in the non-observed point sections.

Figure 2 depicts an example of the result of this analysis. The plan view (top) is a TIN of the ground classified points from the lidar data. The profile (lower part of the figure) shows the line draped over the lidar data in white and the profile derived from the simulates survey data in green. The superimposed faint grid has a spacing of 1 m X 1 m. You can clearly see where the "survey" sample points are located

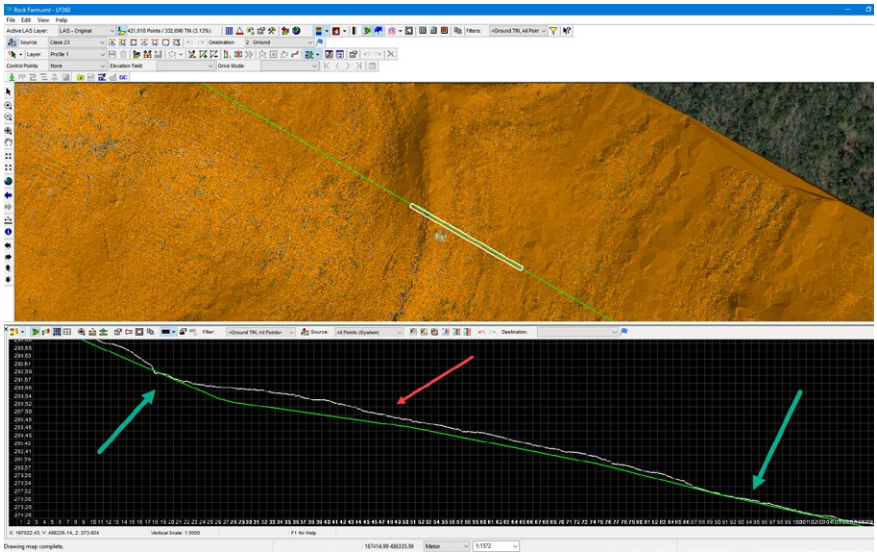


Figure 2: Comparing simulated Survey data to a lidar point cloud

(green arrows in **Figure 2**). Here our simulated survey profile (again, the green line) is tangent to the "true" data (white line). However, as we move away from the survey sampled points, the deviation between approximation and the true surface becomes fairly dramatic. In the vicinity of the red arrow in **Figure 2**, the separation is about 2 meters!

Now I know you can make all sorts of arguments about careful profiling along break lines, sampling based on terrain and so forth but you would be missing the point (pun intended) by going down that rabbit hole. For anything other than a true planar surface, you would have to collect survey data at the same density as the lidar data to compare single point collection accuracies. In fact (this is fodder for a different article) you could have an RMSE of 25 cm in the lidar data and, if these errors were unbiased and randomly distributed, still have a much more accurate answer than using traditional survey methods.

The bottom line here is that a drone lidar mapping approach with lower per sample network accuracy than the survey gear will always give you a better answer than traditional survey so long as you:

- Use checkpoints to debias the lidar data ("Z" bump—a different article)
- Carefully ensure the lidar data are correctly calibrated. This is easy to do with tools in True View Evo (or LP360 for sUAS)
- Do a decent job with the ground classification (again, easy to do with tools such as True View Evo/LP360, TerraScan, etc.)

I am always very interested in your thoughts along these lines so please send me an email with your comments and observations.

Lewis Graham is the President and CTO of GeoCue Corporation. GeoCue is North America's largest supplier of lidar production and workflow tools and consulting services for airborne and mobile laser scanning.

Accuracy—Needs Versus Wants

We have a very conservative network accuracy specification of 5 cm RMSE for our True View 410 "utility" grade 3D Imaging System (lidar and oblique camera combination). When discussing needs with surveyors, I very often hear the magical 1/10 foot requirement (I wish someone could tell me the origins of this specification!). This is a 1.2 inch (3.048 cm) so let's just say 3 cm requirement. This is achievable with drone lidar if ground control is used and the data are debiased. However, do we really *need* this for common applications such as topographic mapping or do we just *want* it because surveyors always want the highest accuracy, irrespective of need?

We were recently working with a surveying company who were interested in using drone-based lidar for topographic mapping. A typical project could be a vegetation (e.g. tree) covered parcel being mapping for land development. The initial data model is used for overall site planning and initial clearing estimates.

I asked how this work is performed if you do not have a drone. The answer is one or more of RTK, digital leveling or total station depending on what was appropriate for the particular situation. Well, we do not need to ask the accuracy of these devices—it is generally sub-centimeter relative to the local differential reference (e.g. base station) or monument. However, the big consideration is the nature of the terrain and the density of profiles or points to be collected. Drone lidar is a very dense collection with an average nominal point spacing of 8 cm or even tighter for a typical True View 410 topo project. This means we are saturating the terrain with an average of about 150 points per square meter.

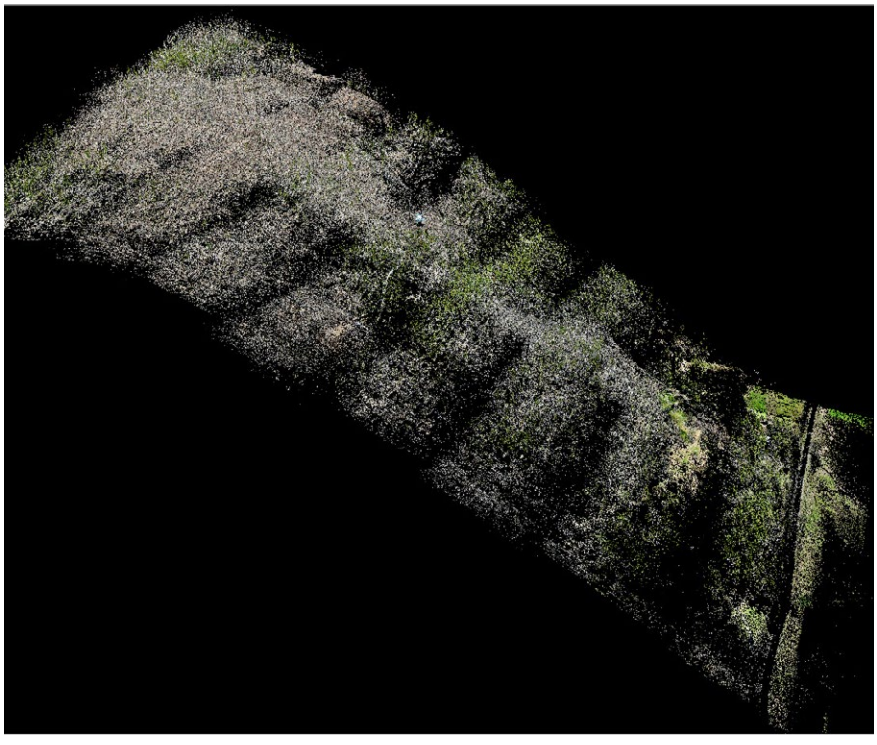


Figure 1: The Rock Farm

Now compare this to the sampling that occurs in conventional surveying. If I could collect a point every 10 m, I would have an average sample density of 1 sample per 100 m^2. Each of these samples would exhibit very high vertical accuracy (say 1 or 2 cm RMSE relative to a reference) but what happens between these samples? If the area is flat as a pancake, you are good to go. However, if you are working in rugged terrain, all bets are off. The terrain can vary dramatically between your samples, severely degrading overall accuracy. Ironically, the rougher the terrain, the denser you need your samples but the more difficult they are to obtain with conventional survey.

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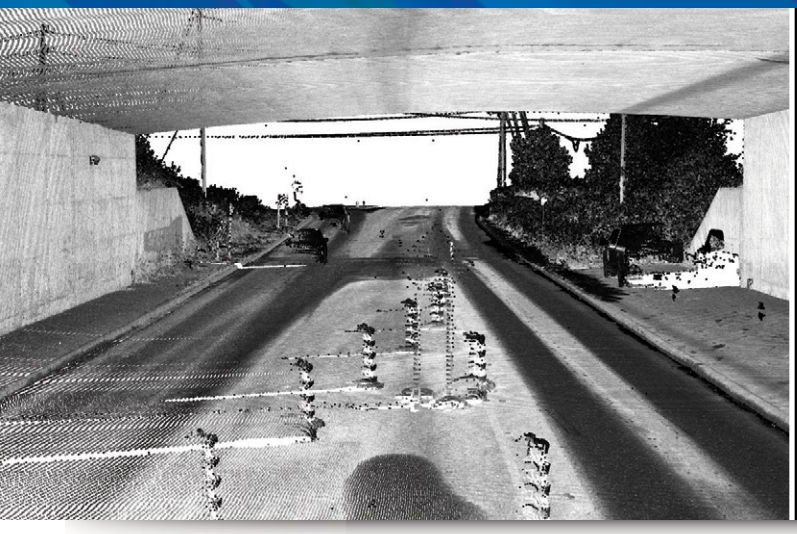

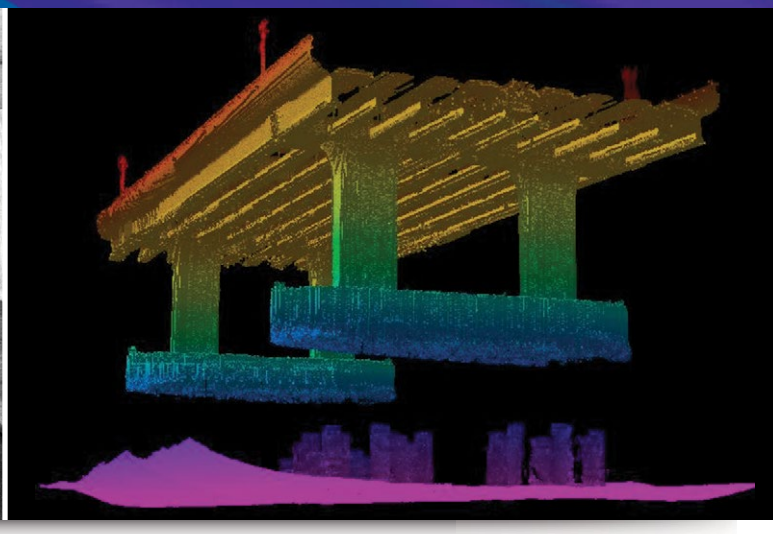

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