VOLUME 9 ISSUE 3

LIDAR MAGAZINE

MAY/JUNE 2019

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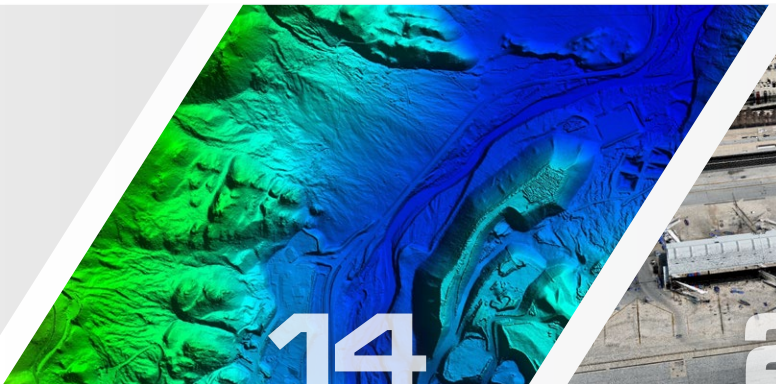

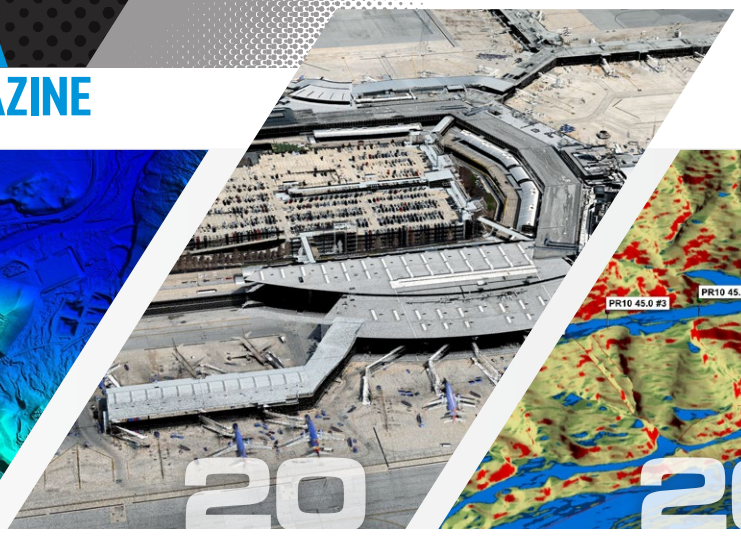

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An integrated lidar-derived topobathymetric model of the river Kootenai (northern Idaho), showing extensive braiding, depicted via bare earth (brown) and subsurface bottom (blue).

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DR. A. STEWART WALKER

The Right Place and Time

Perusing the news on one's phone every morning can be a dispiriting experience, as so many of the constants that have safeguarded those of us in many countries of the world for decades, such as environmental, democratic and security constructs, have become stochastic. I have been lucky to enjoy a life sheltered from many of Hamlet's "slings and arrows of outrageous fortune", but the California wildfires and, very recently, the tragedy at the Chabad of Poway, less than a kilometer from my home, bring them uncomfortably to life.

The above reflection implies that perhaps we insufficiently appreciate good kismet. Talking to another geospatial professional last week, however, I marveled at my luck. While in principle "retired", I have the privilege of reading, writing, traveling and participating in multiple ways in the geospatial profession and community. In March I attended the Esri Partner Conference in Palm Springs—a beautiful setting in the cooler months—and saw how the host company, founded 50 years ago, and the remarkable community of users and partners that it leads, develop geospatial thinking and practice. Later in the month, I was invited to a meeting in Toronto of the Council of the International Society for Photogrammetry and Remote Sensing (ISPRS), comprised of six eminent geospatial academics wrestling with the guidance of global research and international cooperation in photogrammetry, remote sensing and their applications. The milestones leading to the XXIVth ISPRS Congress in Nice, France, in June 2020 are upon us—it will be a conference not to miss, an opportunity to learn about the critical trends in lidar. My role in Toronto was to represent The ISPRS Foundation, which is ISPRS's charitable arm supporting ISPRS activities in many ways, the most rewarding of which is travel grants to students from developing countries to enable them to attend ISPRS events and present their papers.

On the same trip I was able to visit two leading players in our lidar world. Applanix and Teledyne Optech. Articles are in preparation, which I hope will transmit the competence of these long-term stakeholders, blended with their palpable excitement at new developments in both the technology and the market.

The SPAR 3D/AEC Next event in Anaheim, California in May was part of the Diversified Communications portfolio and once again the firm acquitted itself very competently. There were 1900 attendees, a significant increase over 2018, from 33 countries, all 50 states and the District of Columbia, and seven Canadian provinces. The bustling trade show accommodated 118 exhibiting companies. The conference encompassed more than 80 sessions and five keynote presentations. More than 60% of the attendees were first-timers. This was the

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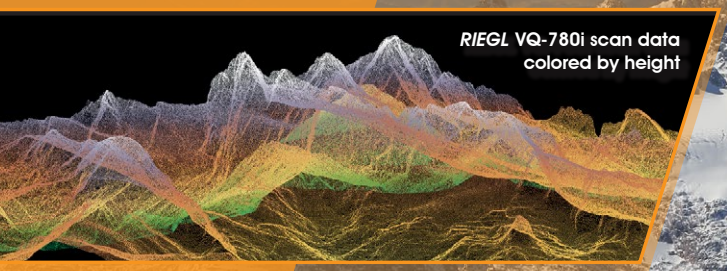

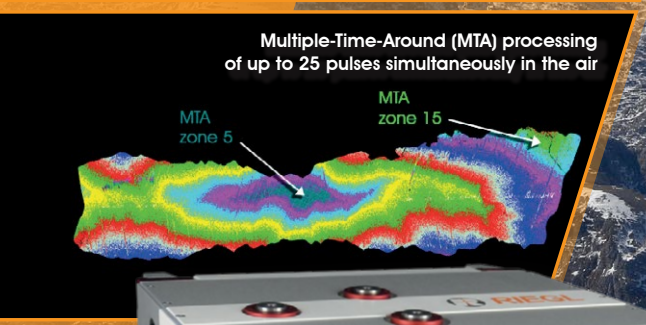

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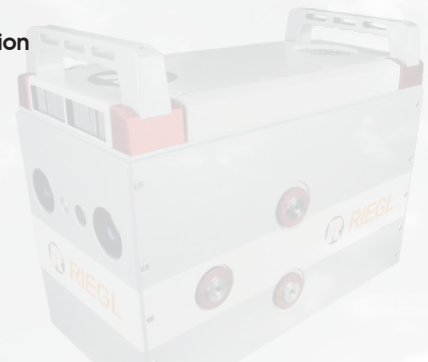

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second instance of the joint event and, after two successful years in Anaheim, Diversified Communications is moving it to Chicago—mark your calendars for 3-5 June 2020. One of the frustrations of my role at such events is that I cannot cover every session and exhibitor. But, at risk of being too eclectic, I will give my enthusiasm full rein. After the product previews on the Tuesday morning, I moderated a session on "AEC project case studies". It was superb! Five incredibly highly qualified speakers who were well prepared, eloquent and kept to time, described the provision by Firmatek of UAV-lidar services for Turner Mining Group; . the use by Corgan of augmented reality on projects at LAX; Borton-Lawson's generation of business benefits for the nuclear industry of 3D reality capture. All the talks were superbly illustrated, to the extent that the nuclear one jump-started memories of *K-19: The Widowmaker*! I've already pressganged some of the authors for articles.

On the Wednesday I relished one of the most fulfilling mornings I have experienced at a conference for many years. MiMi Aung from NASA described the Mars Helicopter project with enthusiasm and animation that had the audience spellbound. She outlined the challenges of delivering a UAV rotorcraft to Mars then flying it autonomously in the Martian atmosphere—and how NASA has risen to each one. Twelve hours later, I encountered her again, in a social event, where she was similarly enrapturing Jon Snoddy of Walt Disney Imagineering, one of the Thursday keynotes. MiMi was followed on stage by Bob Sutor of IBM Research to tell us about quantum computing, where it is now and where it is going. He was brilliant too and by the end I was beginning to understand it. After catching up with Phoenix Lidar Systems during the break, I took in an AEC session on historic preservation—three more fabulous presentations. Speakers from Leica Geosystems, Johns Hopkins and structural engineers Silman described the scanning, modeling and analysis of, respectively: Frank Lloyd Wright's Taliesin West near Phoenix, Arizona; Cologne cathedral—with very scary photos of scanning stations on the towers—and CERN's Large Hadron Collider near Geneva, Switzerland; and the historically important but deteriorating concrete structure of Harvard Stadium. Next, we gentlepersons of the press were invited to a luncheon to hear Bentley VP Bob Mankowski address the topic, "Digital twin technology for digital cities", a well illustrated talk on the applications of his firm's latest product offerings. What a way to spend a morning!

It's natural to rhapsodize about events where we network and hear the latest developments in our own fields. The collegial atmosphere of conferences is stimulating *per se*. Everything seems vibrant and inspiring. But is it real? Can we have a perspective? Glance at pages 6 and 7 of this issue. Global Marketing Insights has released a research report on the global lidar market and the statistics are remarkable. The firm estimates that the market will grow from $1b in 2019 to $10b in 2025, a compound annual growth rate (CAGR) of more than 35%. I've seen many of these research reports and they're all limited by the sample of companies interviewed in the underlying survey; yet I've seen very few that predict growth of this magnitude. CAGRs are given by market segments: >25% for topographic lidar; >30%, bathymetric; >37%, UAV; >50%, driverless cars; >32%, environmental. The North American market will grow faster than the European one, and by 2025 UAV-lidar will generate almost as much revenue as airborne. There will be partnerships and mergers as firms jostle for places on the food chain. I think we're in the right place at the right time and the excitement of my recent travels is a authentic reflection of the industry in which we're fortunate to be participating.

Finally, wearing my ASPRS hat, I have become aware of ongoing work by its LIDAR Division. A new working group for Lidar Accuracy Research is focusing on the uncertainty guidelines and various related specifications. Another working group for Alternative Point Cloud File Format Research exploring efficient methods to handle point clouds. I will pursue these groups for an article on their activities!

Readers will tolerate—or dread—my penchant for reporting, in a whimsical way, items I read in *The Economist* from time to time that are in some way related to lidar. Importantly, in a briefing on Chinese mobility, the newspaper reported that, "RoboSense, a startup in which Alibaba, SAIC and BAIC [a Chinese carmaker] have all invested, is taking on Western firms developing the lidar sensors that tell autonomous vehicles about their surroundings."[1] We won't even mention 5G! But there are other Chinese players in this market and we have an article ready to print about one of them. This will be another demonstration of the impetus provided to R&D by the AV market overflowing into the UAV-lidar world.

A. Stewart Walker // Managing Editor

1 Anon, 2019a. Great wheels of China, *The Economist*, 431(9137): 19, 6 April.

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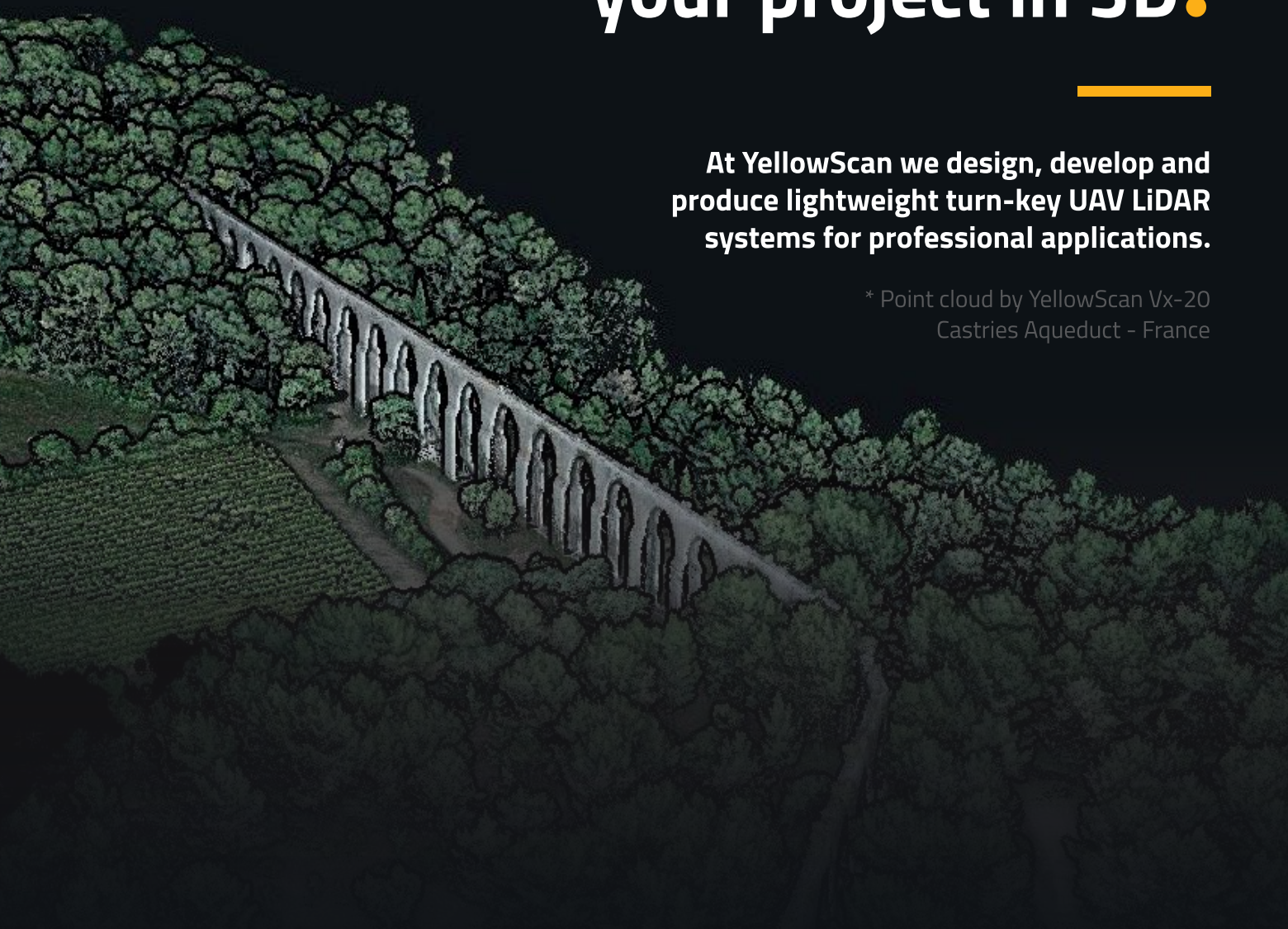

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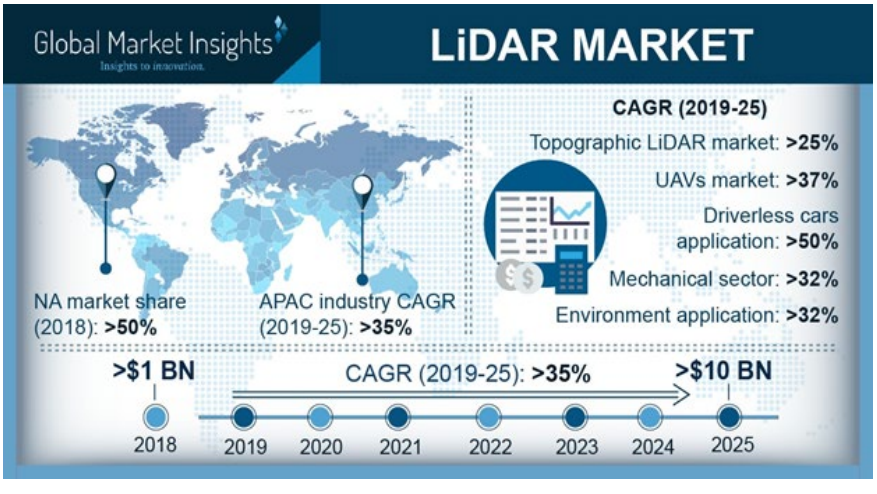
Lidar Market to reach USD 10 billion by 2025

The global lidar Market is set to grow from its current market value of more than $1 billion to over $10 billion by 2025, according to a new research report by Global Market Insights, Inc.

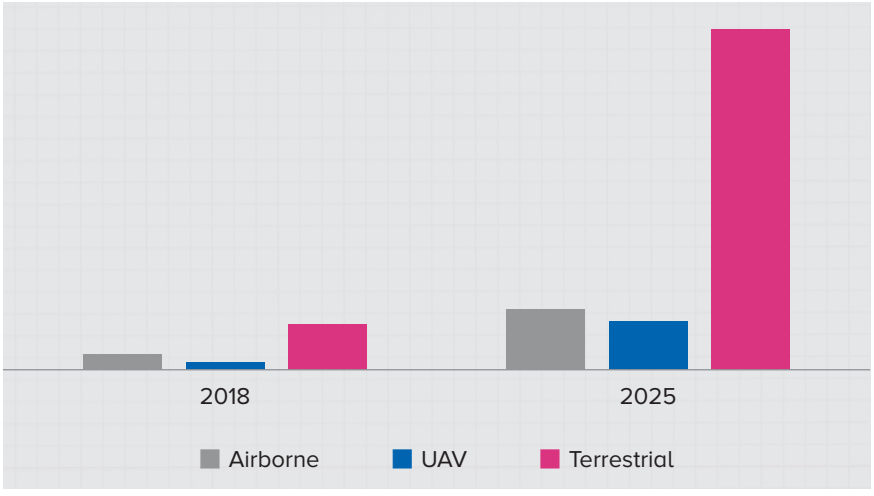
There has been a rise in the demand for 3D imaging solutions owing to the increasing development of smart city projects and its expanding civil engineering and manufacturing applications. The existing traditional 3D imaging technologies, such as radar, cannot detect small objects, preventing its usage in high-precision applications. Lidar technology uses shorter wavelengths that allow it to detect miniscule objects with a high degree of accuracy while developing an exact 3D model of the object. This characteristic has opened a new paradigm of possibilities to solve complex tasks, specifically in factory automation, robotics, and manufacturing sectors, encouraging companies to use lidar solutions due to their ability to solve various complex problems while simultaneously developing high-precision 3D models.

Lidar solutions are increasingly used in UAVs to produce high-resolution digital surfaces and elevation models for numerous business applications. Historically, enterprises used a bespoke component for every application. With the advent of lidar technology, companies are using lidar devices mounted on UAVs, which serve as a multifunctional 3D mapping system. This further reduces the overall size and production cost of manufacturing the entire UAV system, making lidar a viable and affordable alternative for use on UAVs.

> “There has been a rise in the demand for 3D imaging solutions owing to the increasing development of smart city projects.”



The bathymetric lidar market is projected to grow at a compound annual growth rate (CAGR) of over 30% over the forecast timeline. The changing climatic conditions in coastal areas, rising sea levels, and the increasing severity of extreme natural events have renewed the focus on better understanding of coastlines. Bathymetric measurement systems survey near-shore land and sea surface areas to help identify potential risks in coastal regions, providing a cost-effective



and efficient technology solution for simultaneously capturing both land and sea data to develop a detailed elevation model along coastlines. The technological advance in the bathymetric lidar market landscape is also augmenting its adoption. Aircraft are using multiple sensors, which are designed to provide an integrated 360-degree view over large areas, faster throughput, enhanced reflection calibration between flight lines, and enhanced point density. The advances in cloud computing and big data processing have driving its usage in long duration surveying and mapping applications.

The mechanical lidar market is anticipated to register a growth rate of over 32% during the forecast timeline. This is attributed to the widespread demand for mechanical lidar devices in driverless cars. The companies operating in the automotive sector are exploring new ways to drive the price of manufacturing mechanical lidar systems. Solid-state technology is yet to be commercialized and is still in the development phase. A large number of R&D activities is expected to drive the innovations in the solid-state lidar market.

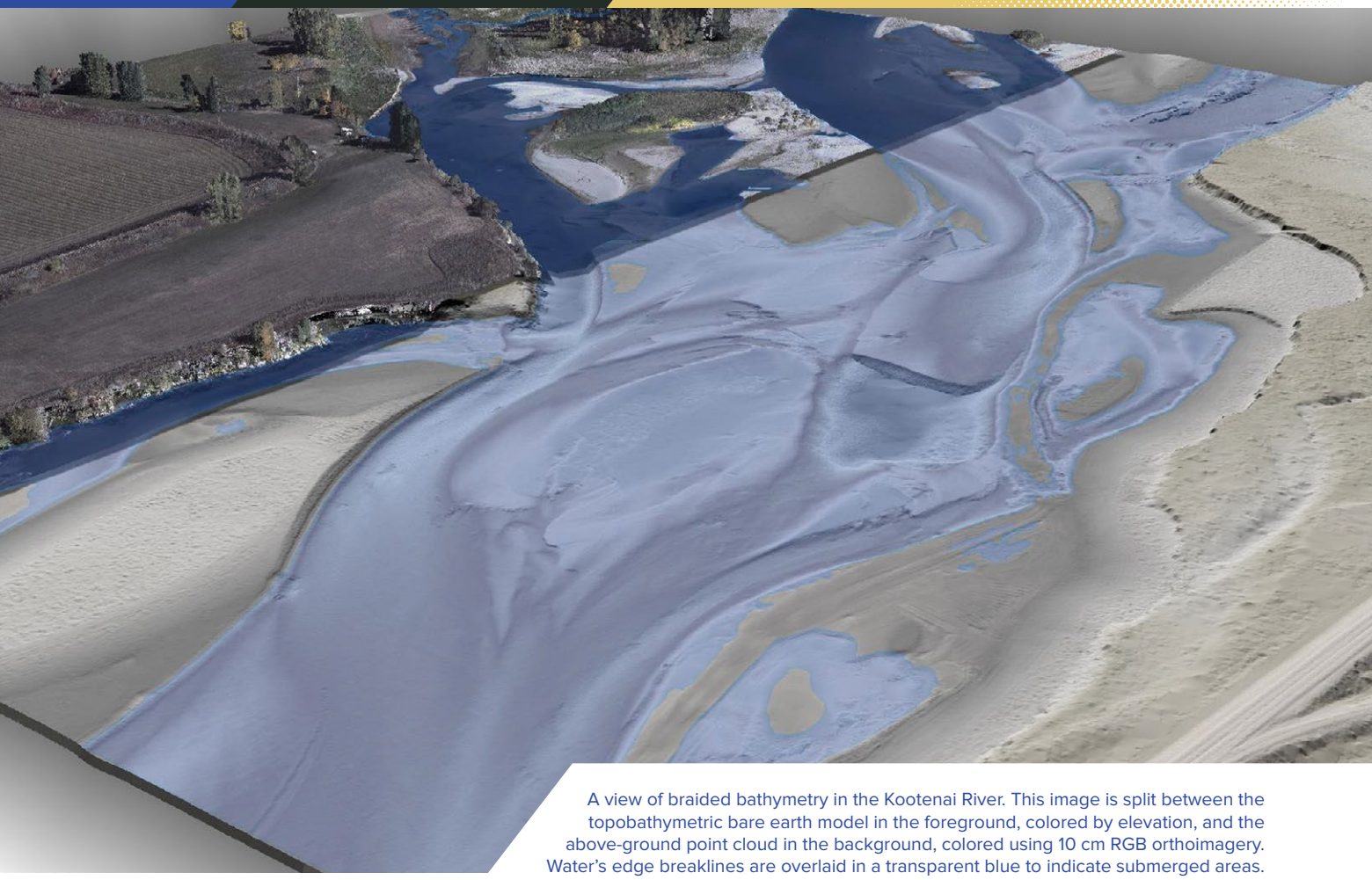
U.S. lidar Market Revenue, By Product, 2018 & 2025

The environmental lidar market is expected to register a growth rate of over 32% during the projected time period. Lidar technology provides real-time data for numerous geoscience applications to develop accurate, high-resolution maps and 3D models. The technology has been used to study the ecosystem of various wildlife species including different types of birds, insects, and animals. It is used to measure the vertical density of forest canopy to monitor forest fires and identify certain forest areas that enhance the productivity of wood quality. Lidar technology helps plan and manage a forest while increasing environmental quality.

The European lidar market is expected to grow at a CAGR of over 20% over the projected time period due to the increasing use of advanced lidar solutions on various engineering projects at a large scale. Another factor that has acted as a catalyst in the usage of lidar solutions is the rising use of UAVs for various recreational and commercial purposes. There has been an upsurge in the number of supportive government initiatives, encouraging enterprises to invest in lidar-based research, along with the adoption of lidar technology for numerous public-sector applications such as flood relief and management.

Players in the lidar market are building partnerships with other lidar companies to strengthen their positions in the market. In June 2018, for example, Innoviz joined forces with HiRain Technologies to develop new, advanced versions of solid-state lidar devices for China-based car manufacturers. The companies are also focusing on fundraising activities to expand their operations globally. For instance, in November 2018, AEye, a start-up based in the U.S., raised USD 40 million in a series B funding round to scale its operations.

Source: https://www.gminsights.com/pressrelease/lidar-light-detection-and-ranging-market



A view of braided bathymetry in the Kootenai River. This image is split between the topobathymetric bare earth model in the foreground, colored by elevation, and the above-ground point cloud in the background, colored using 10 cm RGB orthoimagery. Water's edge breaklines are overlaid in a transparent blue to indicate submerged areas.

Overcoming Hurdles to Modeling River Bathymetry

Topobathymetric lidar and hyperspectral imaging combine to deliver new, detailed insights into submerged terrain

BY MICHAEL SHILLENN

Modeling the bathymetry of rivers presents significant challenges for GIS professionals, as they try to model submerged terrain with the same accuracy and resolutions that they require for terrestrial landscapes. While boat-mounted sonar has worked to gather inland bathymetry data, it has limitations for shallow waters.

New technologies—such as topobathymetric lidar combined with hyperspectral imagery—present opportunities to analyze and model inland shallow water floodplains and riverine environments in ways not possible before. A U.S. Geological Survey (USGS) project, which started in Fall 2017, set out to evaluate the promise of

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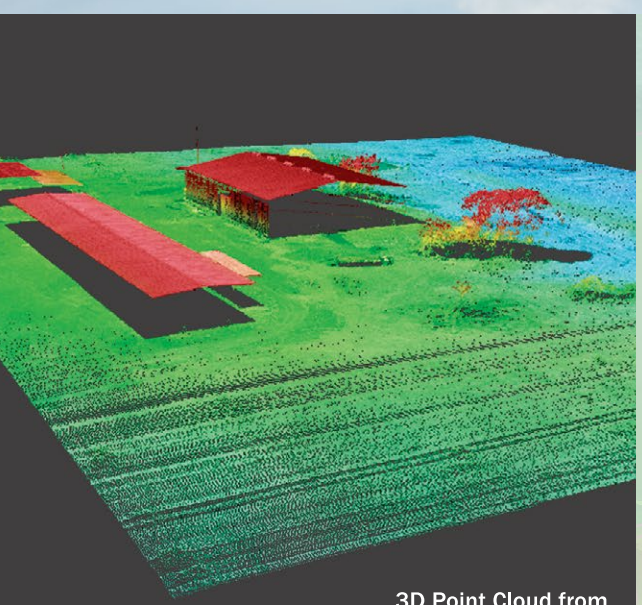

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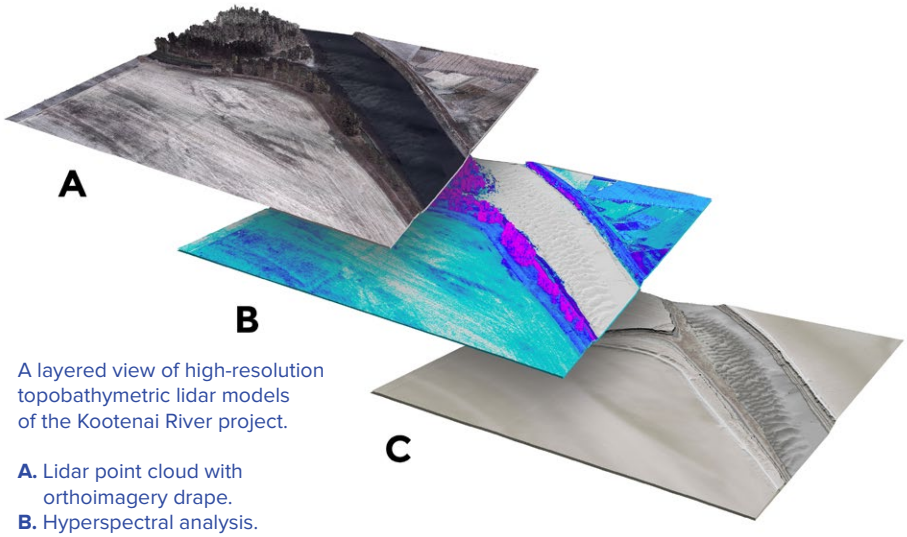
these technologies for use in national mapping programs, and assess their ability to provide valuable new insights into water resource management and aquatic habitats.



A layered view of high-resolution topobathymetric lidar models of the Kootenai River project.

A. Lidar point cloud with orthoimagery drape.
B. Hyperspectral analysis.
C. Lidar -derived bare-earth and bathymetric elevation model.

USGS research and the Kootenai River

USGS contracted Quantum Spatial Inc. (QSI), which has been perfecting the use of these new technologies to map shallow river systems since 2012, to collect and process topobathymetric lidar, natural color imagery and hyperspectral imagery for a 54-mile stretch of the Kootenai River in northern Idaho. This complex endeavor was designed to provide USGS with a better understanding of the river, while evaluating the potential large-scale commercial value of new techniques for mapping inland bathymetry.

USGS's inland bathymetry research was instrumental in the evaluation phase, focusing on a diversity of pilot rivers to test the ability of topobathymetric lidar to characterize fluvial patterns and processes, and identify optimal conditions, as well as standardized collection and processing techniques. Because research and restoration activities were already underway, USGS identified the Kootenai River as a perfect pilot site to evaluate this approach.

The Kootenai River flows from its headwaters through a rugged region of southwestern Canada, then through Montana and Idaho, before meeting the Columbia River 500 miles later. The watershed drains a 19,000-square-mile area, spanning six different biomes. It supports a rich variety of flora and fauna, and is a primary source of drinking water and agricultural irrigation along its course. Given this diverse reliance on the Kootenai by fish, wildlife and humans alike, it has become a hotbed of research on fluvial processes, species protection, habitat enhancement, restoration, and flood dynamics for a collection of scientists, environmental groups, tribes and local communities.

Getting the project off the ground

The Kootenai River project was complex from the start, involving three technologies: lidar for topobathymetric data, simultaneously acquired natural color imagery for ancillary information, and hyperspectral imagery for depth and flow modeling. This combination created challenges for the flight team, which had to collect three disparate types of data within the same time frame. The deployment required outfitting and installing the hyperspectral sensor with the topobathymetric lidar (and camera) sensor into a single two-hole aircraft. This complex combination of technology included the Riegl VQ-880-G topobathymetric lidar sensor with an integrated 29 megapixel Prosilica GT6600 digital camera, and an ITRES CASI 1500H hyperspectral imagery sensor provided by USGS. The project was among the first riverine areas of interest to test the settings of the then new 1.5 Secchi Depth Riegl VQ-880-G system and its performance for modeling rivers in the Pacific Northwest.

The lidar sensor was set to collect data at QL1 pulse density of 8 pulses/m^2 for topographic surfaces, and at least 2 pulses/m^2 for bathymetric surfaces; the natural color imagery was co-acquired with the lidar at 10 cm GSD; and the hyperspectral imagery was collected at 50 cm pixel resolution.

Once the sensors were installed on the aircraft, QSI evaluated and optimized flight plans for the particular altitude, field of view and swath width required to meet specifications for terrain resolution. Utilizing one aircraft for a single deployment to the study area increased efficiency, and also significantly reduced costs.

The Kootenai project involved close collaboration between USGS scientists, University of Wyoming (UW) fluvial geomorphologists, River Design Group (RDG) restoration engineers, and QSI's team of project managers, acquisition managers, flight team, ground crew and lidar technical experts. With a short six-day acquisition window of September 24-29, 2017, the team had to coordinate and collect all ground and airborne data among multiple partners in the proper order, while also working within the confines of weather.

To help understand drift patterns and larval fish dispersal, the hyperspectral imagery was collected during a specific window after release of a red tracer dye into the river. Owing to concerns that the dye would impact water clarity, however, lidar had to be collected first. All ground operations—measurements for turbidity, setting hyperspectral targets for ground control, release of the dye, setting lidar terrestrial and submerged QA points and waveform targets, and collecting verification depth profile and cross-section data (USGS)—had to be carefully timed and orchestrated with respect to each other and to the airborne flights. RDG, which was in the midst of a channel-bed dredging operation upstream of the Kootenai project site, also had to halt operations for 48 hours before and during the lidar collection to ensure there was no impact on turbidity from sediment disturbance.

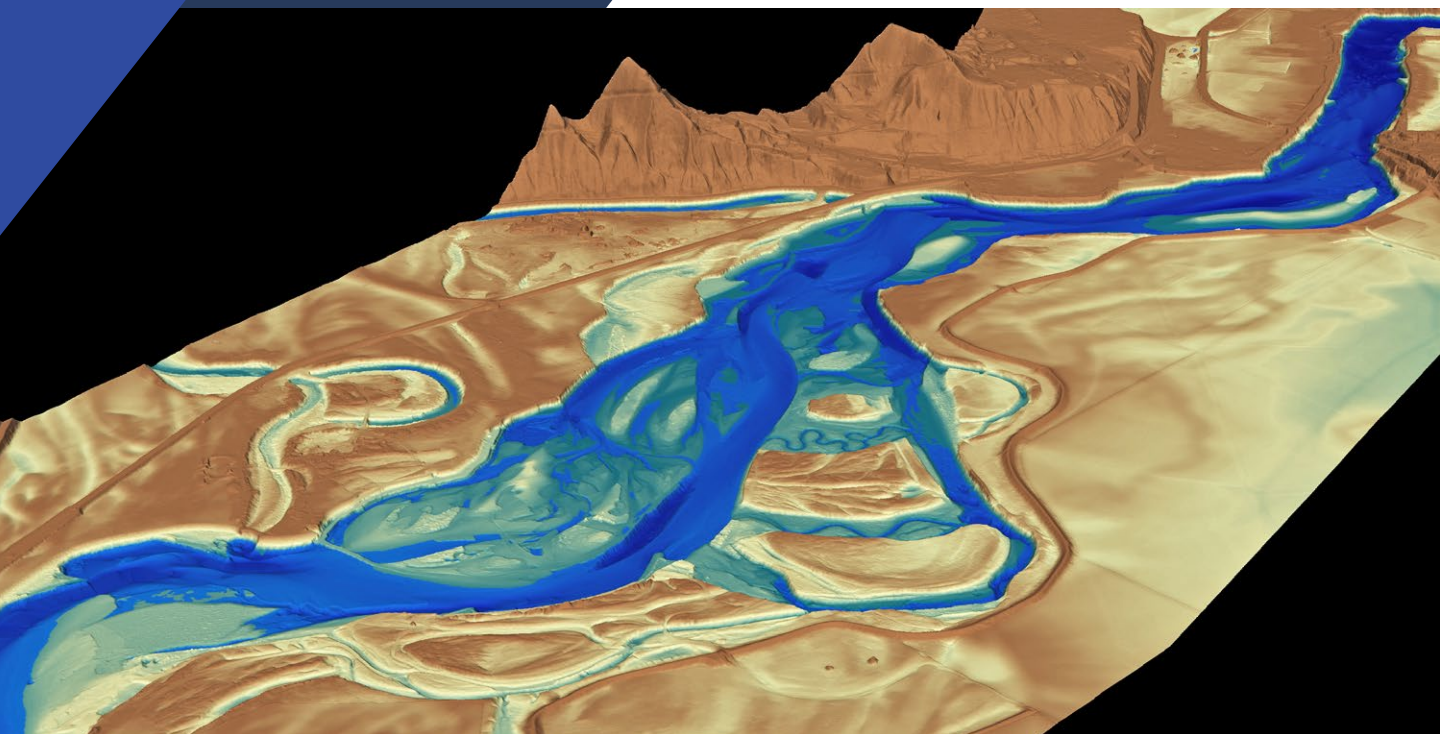
With ideal river conditions in the forecast, a hold on sediment dredging, and a multi-agency ground team at the ready, the QSI acquisition team quickly collected more than 20,000 acres of topobathymetric lidar data and ortho-imagery within a two-day window, then

An integrated lidar-derived topobathymetric model showing the extensive river braiding, depicting both bare earth (grey) and subsurface bottom (blue) terrain.

12,851 acres of hyperspectral imagery two days later.

Once the data was collected, lidar and orthoimagery were quickly processed in parallel for delivery by mid-December 2017. There were three different, but interdependent, workflows involving multiple subtasks and coordination among two firms to keep the post-processing workflow efficiently coordinated and on schedule.

QSI processed all lidar data and color natural imagery, which was orthorectified using the lidar-derived digital elevation model (DEM). There were many subtasks involved in topobathymetric lidar processing, including correction for light refraction through water, an evaluation of the impact of water clarity and surface reflectivity on results, and treatment of the waveform data. ITRES ran preliminary processing and quality control on the hyperspectral data, worked with the lidar-derived DEM provided by QSI for the orthorectification step and the ITRES proprietary geometric correction software, then passed the imagery to QSI for final processing and quality assessment.



An integrated lidar-derived topobathymetric model showing the extensive river braiding, depicting both bare earth (brown) and subsurface bottom (blue) terrain.

All data was expected to meet requirements for data quality, resolution, accuracy and deliverables in the USGS's *Lidar Base Specifications Version 1.3* and the National Ocean and Atmospheric Administration (NOAA) bathymetric modeling standards. These were also requirements for meeting predictive model input requirements.

Lidar resolution was 11 points/m^2 for bathymetric surfaces mapped and 8 points/m^2 for combined topographic surfaces. The lidar elevation data was accurate to within 5.6 cm of true ground, exceeding the USGS vertical accuracy requirement for non-vegetated vertical accuracy of 18 cm or less. These values were corroborated by independent assessments from USGS-collected field data. Water clarity at the time of collection resulted in depth penetration to approximately 3 m. These results collectively attested to the capacity for topobathymetric lidar to accurately model inland bathymetry.

Finally, to evaluate the full value of topobathymetric lidar in extracting useful information for river channel bathymetry, QSI processed the full waveform data from the topobathymetric sensor, which it delivered to USGS along with raw discrete return swath files.

Using the Kootenai dataset, QSI worked closely with sensor supplier RIEGL to improve upon the information that can be extracted from the full waveform data. Inland bathymetric point targets were placed on the river bottom to test automated target identification. Preliminary results indicated that better signal processing of the waveform is possible, where meaningful returns are better filtered from noise, represent deeper targets and maintain higher fidelity to the inherent information present in the data. RIEGL is incorporating these results into its RiProcess software, which will ultimately lead to improved automated processing of bathymetric lidar.

Impact on the future of river ecology

The Kootenai River project led to several societal and economic benefits on both a local and global scale. Results from the study have furthered the understanding of the Kootenai River ecology and similar systems, while advancing understanding of topobathymetric lidar

base specifications and requirements for widespread commercial use.

Local natural resource and planning managers of the Kootenai River watershed were able to gain a valuable understanding of flood risk and management strategies, as well as erosion and sedimentation patterns. High-resolution flood maps from bathymetric data are improving insights into the impact of floods, flood risk, and inundation patterns to improve community preparedness and resiliency for the Kootenai River watershed, a USGS Water Mission Area priority area under the Flood Inundation Mapping Program. Suan Ireland, fish and wildlife department director for the Kootenai Tribe, also noted how the work will support their existing habitat restoration projects and could be useful for future restoration project design, implementation and biological assessment.

For dammed rivers, such as the Kootenai, the project also fosters a better understanding of sedimentation, instream and dam-related sediment movement patterns, erosion, slope failure, geophysical impacts on water quality and fish habitat, and stream bed evolution.

The project delivered information on fish habitat and local ecology to the Kootenai River Habitat Restoration Program and other ongoing pallid sturgeon photo fisheries research studies in the region. The lidar and hyperspectral data also provided invaluable insight into the ecology of the Kootenai River, including aspects of flow dynamics, connectivity and channel characteristics that define habitats for recreational, threatened and endangered fish species, such as sturgeon and burbot.

The surface models from this study will enable modeling and imaging of geomorphology, substrates and river bed evolution patterns critical to restoration planning. Moreover, the hyperspectral imagery and dye dispersion patterns revealed drift and flow dynamics that are helpful in understanding thermal dynamics, tracking pollutants, tracing nutrient drift patterns and following the passive migration of larval fish. Armed with new data, biologists and natural resource managers gained insight into the speed and distribution of fish as they move downstream from Kootenay Lake in British Columbia. Furthermore, with a new understanding of the river's geomorphology, fisheries biologists and restoration professionals can now make more targeted efforts toward helping restore in-stream habitat for fish.

For the Kootenai and other river systems, access to better data also contributes to better predictive modeling of natural processes. The data from this study have contributed accurate channel-geometry data as input to flow, sediment transport, and river-bed evolution models developed by the USGS, U.S. Army Corps of Engineers and U.S. Bureau of Reclamation.

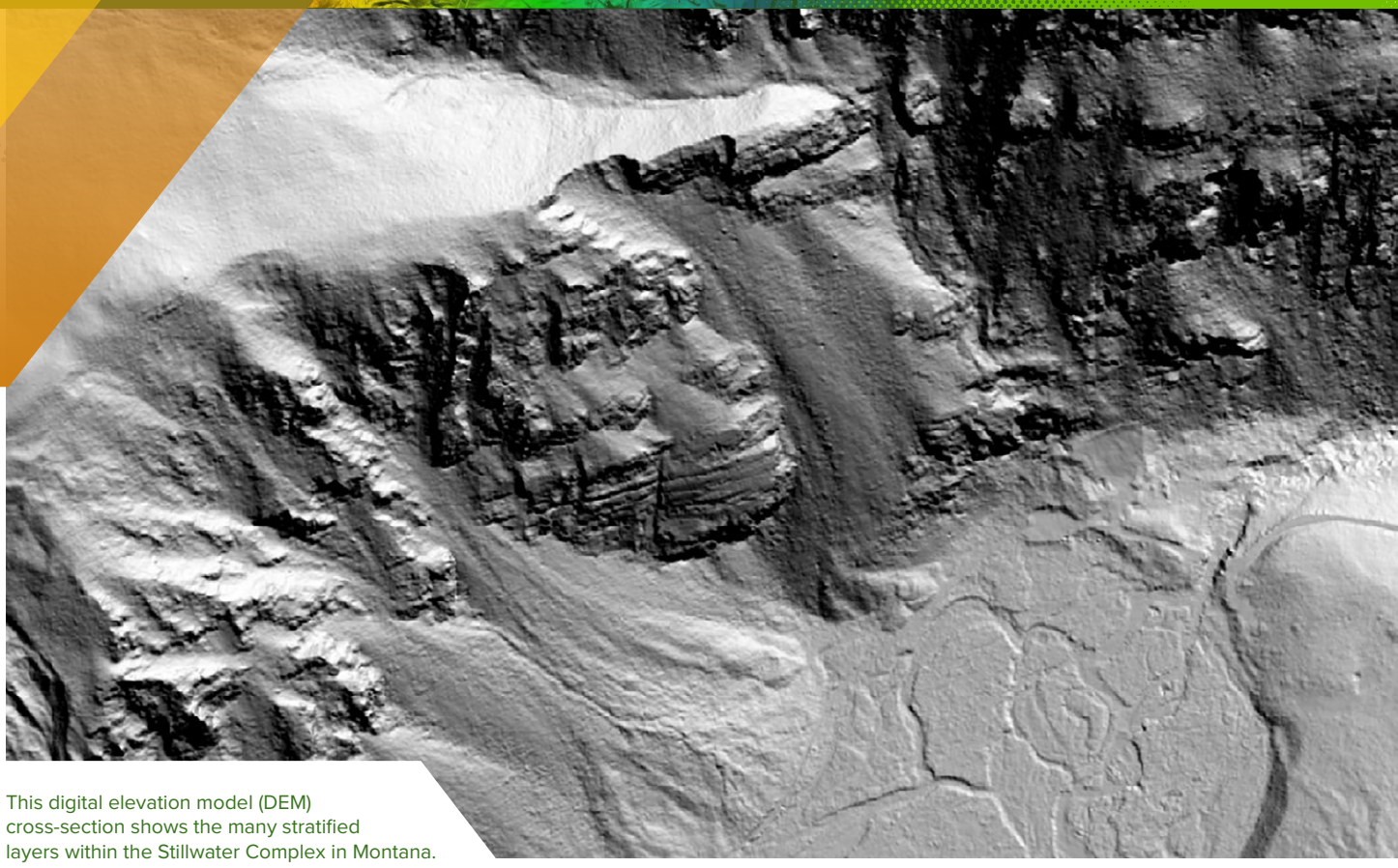
Project contributions to geospatial innovation

The Kootenai River project has contributed in significant ways to the geospatial field, as the larger lessons learned from the project have helped to redefine the marketplace for lidar mapping. It provided evidence that topobathymetric lidar can fill the gaps in topographic modeling for underwater landscapes. By contributing to USGS's inland bathymetry research, the Kootenai River project fed valuable information into the 3D Nation Requirements and Benefits Study, led by USGS and NOAA. 3D Nation aims to unify all national elevation efforts and provide a consistent set of standards and guidelines across geographies and land forms. The initiative also aims to evaluate and integrate the technology, systems, data and services for coastal, for example the Coastal National Elevation Database (Co-NED), and inland bathymetry elevation mapping with that for the well-established terrestrial 3D Elevation Program (3DEP).

The Kootenai River project was instrumental in providing USGS with its first official insight on inland riverine bathymetric mapping requirements and solutions. As exemplified by the success of the project, the USGS has determined that when collected under optimal water clarity, topobathymetric lidar can be a cost-effective and more accurate method for surveying riverine study areas compared to traditional methods.

The Kootenai River topobathymetric lidar provided almost complete bank-to-bank coverage of braided and shallow bathymetry areas at a high-spatial density that will help fill critical data gaps in 2D and 3D hydrological modeling applications. Given the vast number of river miles in the U.S., the geospatial industry should expect to see a significant investment of funds to collect topobathymetric lidar in the coming decade, providing opportunities for the continued growth and advancement of the technology.

Mike Shillenn is a vice president and certified photogrammetrist at Quantum Spatial Inc., and serves as the company's USGS Geospatial Products & Services Contract (GPSC) program manager. He has more than 31 years of experience designing, managing and executing a wide variety of geospatial projects for a broad range of clients and end-user applications.



This digital elevation model (DEM) cross-section shows the many stratified layers within the Stillwater Complex in Montana.

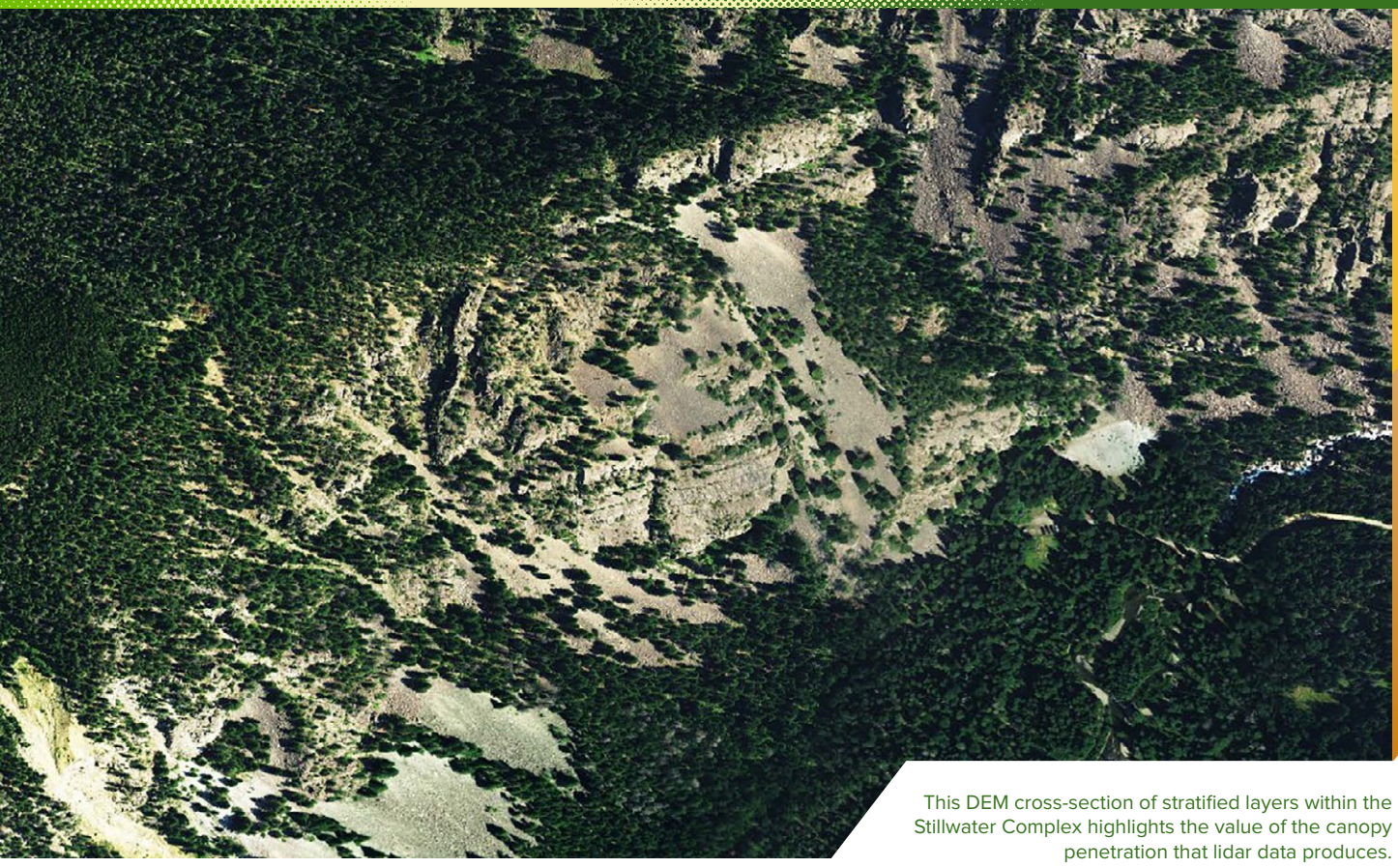
Lidar Enlightens the Search for Critical Minerals

Using lidar to search for important minerals turns decades of work into a few years.

Meeting the need for critical minerals, increasingly used in the production of a wide range of products in modern society, has never been a greater priority. Critical minerals are key components of personal high-tech devices, alternative energy solutions, national defense applications and so much more, making the demand for these minerals and their evasive supply a significant concern for the U.S. economy. Locating these minerals to reduce our reliance on imported minerals can be less labor intensive when using 21st-century tools such as lidar.

Critical minerals have become part of every day life. They are needed for the manufacture of touch screens in most electronics, computer chip production, weapons guidance systems, infrared optics and lasers, as well as in industry, agriculture, manufacturing and construction. Critical minerals are needed to

BY MICHAEL MEISER



This DEM cross-section of stratified layers within the Stillwater Complex highlights the value of the canopy penetration that lidar data produces.

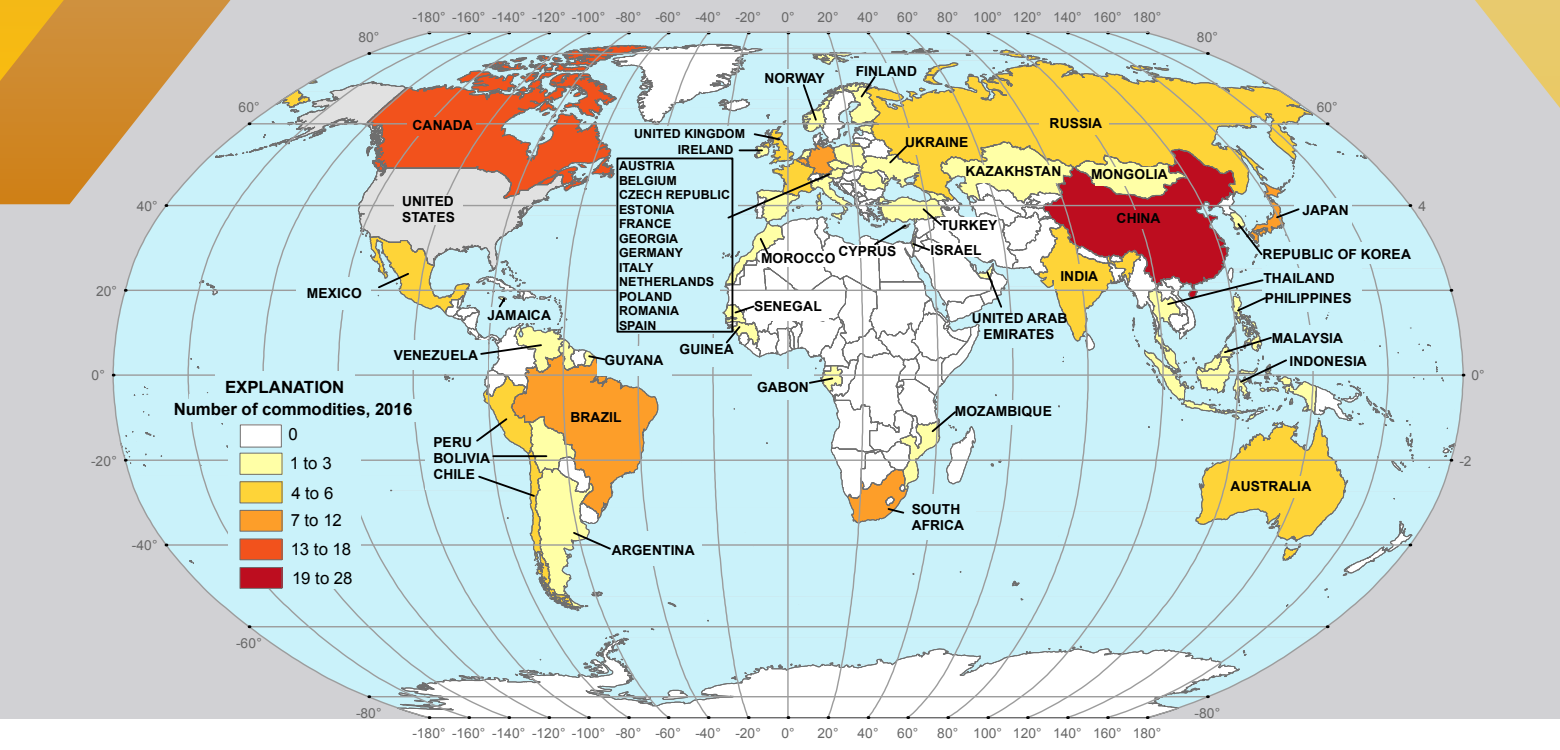
produce batteries, jewelry, pharmaceuticals, health and beauty products, paint, fire-retardant materials, oil and gas products and many other materials.

In the U.S., more than 90 minerals are tracked and evaluated by the U.S. Geological Survey (USGS) Mineral Resources Program. Mineral resource potential, production, and consumption are monitored and, from this, some minerals are determined to be critical commodities; meaning, they have important uses, no viable substitutes and face potential disruption to the supply. Additionally, several more of these commodities, while not considered critical, are still important for many uses. According to recent data reported on the USGS Mineral Resources Program website, U.S. imports for mineral consumption are greater than 50%, with 100% dependency for many of them. Several critical minerals simply do not exist within the U.S. Furthermore, some countries possess a near monopoly on these resources, which could lead to supply disruption with economic impacts on a global scale.

> "Lidar provides high-accuracy data at a resolution that explorers searching for minerals in the past did not have."

Recently, a federal strategy was implemented to ensure a secure and reliable supply of critical minerals located within the U.S. A 2017 presidential executive order was issued to define critical mineral resources, increase private-sector domestic exploration for critical minerals and decrease the country's dependency on critical mineral imports. With a goal of mitigating strategic vulnerability for the security and prosperity of the United States, this directive was issued to identify new sources of minerals and increase mineral production activity at all levels in a safe and environmentally responsible manner. As part of this executive order, access to and utilization of advanced topographic, geologic and geophysical data is essential.

To help accomplish those goals, continued discovery relies on a mixed



The major import sources for mineral commodities upon which the U.S. is net import reliant, as of 2016.

The U.S. Geological Survey

approach, including but not limited to topographic lidar data, geologic mapping and geophysical techniques for exploration, such as aeromagnetic and radiometric measurement surveys. If improved topographic data is available,

it makes mineral exploration safer, more productive and more efficient, while providing methods of detecting alteration and mineralization patterns at the earth's surface. Lidar provides high-accuracy data at a resolution that explorers searching for minerals in the past did not have.

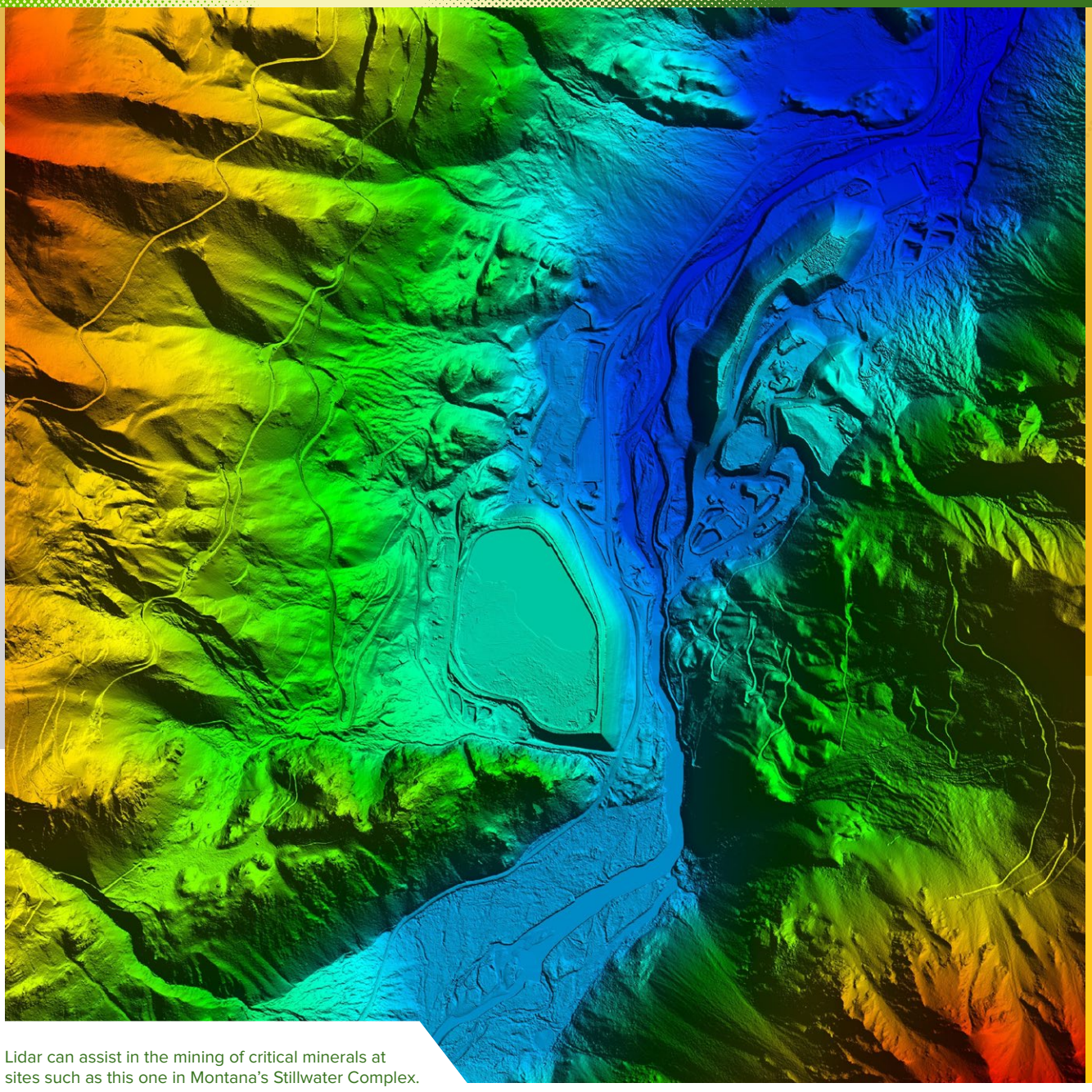
Using lidar is like turning on the lights in a dimly lit room

Many of these critical mineral deposits are found in Western states, in areas that have not been mapped by high-resolution lidar or where the current mapping is outdated.

Using lidar as a tool in mineral exploration provides valuable options for increasing safety and efficiency. If improved topographic data is available, it makes mineral exploration safer, more productive and more efficient, while providing methods of detecting alteration and mineralization patterns at the earth's surface. Lidar also provides source data for accurate base maps, surficial feature identification, soils interpretation, and identification of faults and fractures. The ability to accurately model the terrain and penetrate vegetation is a valuable resource for the detection of features that previously would have been much more difficult to observe.

Mineral deposits have topographic signatures that provide clues to their location and content. This can be related to the way deposits weather or, in some cases, their resistance to weathering. Also, lidar can provide a detailed view of stratigraphic layers in exposed surfaces, which are key areas of investigation that can help geologists pinpoint areas for further exploration. These layers can be seen in the field or with imagery, but lidar enables analysis in a 3D environment before any field work is performed.

Soil analysis is another tool used to explore for mineralized rock, in particular, to understand how the soil in an area came to be in its current location. Is a soil sample on top of mineral-rich base material, or has it moved over time via glacial transport? Analysis of the lidar surface can help



Lidar can assist in the mining of critical minerals at sites such as this one in Montana's Stillwater Complex.

answer these questions by determining if mineral-rich material is underfoot or if it has moved over time, which may lead to identifying more suitable areas to further investigate.

The location of faults and fractures within the topography is critical information in the right hands. Offsets in igneous layering associated with mineralization can cause layers to shift, which when identified on the surface, provide additional evidence and guidance for assessing suitable exploration locations. Additionally, faults and fractures associated with drainage can be direct guides to mineral-rich ore. Understanding these features aids with assessing the integrity of the rocks. Furthermore, identifying water flow assists with protecting against landslides and unexpected water release into the mining areas, making mining sites safer.

All these factors play a part in developing a more efficient and safe operation. Without lidar, reaching similar conclusions would likely take place in the field and require significantly more boots-on-the-ground exploration. Accurate base maps derived from using the lidar data for initial site investigation can help mining experts carefully plan their work from the safety of an office environment, saving great amounts of time and energy.

Mapping Montana for platinum group elements

An example of how lidar can be used effectively in mineral exploration can be found in the Stillwater Complex project that Woolpert conducted in south-central Montana. The project was focused along the northern flank of the Beartooth Mountains, 75 miles southwest of Billings and 25 miles north of Yellowstone National Park. Most of the area lies within the Custer Gallatin National Forest.

The Stillwater Complex contains the most significant U.S. deposit of platinum group elements (PGEs), which are among the rarest metals in the earth's crust. PGEs have a wide range of applications in industrial, chemical, manufacturing, electronic, health care, consumer goods and finance, but are only mined in a few places across the globe. Platinum is used in catalytic converters for vehicles, flat panel liquid crystal displays, and in the medical industry to develop implants and cancer-fighting drugs. The U.S. imports approximately 90% of PGEs, mostly from South Africa and Russia. This deficit, coupled with the tremendous importance of PGEs to the United States, lands them on the critical minerals list. Fortunately, lidar can help improve the mineral's availability.

The Stillwater Complex deposit was discovered in the 1970s. Since the mid-1980s, a few hundred metric tons of platinum and palladium have been mined, but the Stillwater Complex could contain as much as 6,000 metric tons at depth. Those geological estimates indicate enough mineralized material to mine for decades.

Critical minerals include:
aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium and zirconium.

Lidar became a valuable tool for the Stillwater Complex project because it offered the opportunity to view the many stratified layers in ways not possible prior to data acquisition. Subtle cross-cutting relationships within the layers require examination in three dimensions to better understand how the mineralized base material was formed and how best to locate PGEs for extraction. Additionally, the lidar data has allowed geologists to better understand glacial transport history within the complex as well as discover previously undetected faults and fractures hidden by vegetation.

Geologists have now been equipped with a tremendously useful dataset that can help transform their knowledge of the Stillwater Complex, resulting in a more efficient, accurate and safer plan for mineral extraction. Early results have proven highly successful. USGS geologists have underscored the utility of lidar to help extract such a valued resource by comparing it to exploring in a dark room and suddenly having the lights turned on. Early estimates of efficiency gains are on the order of turning what would be decades of work into merely a few years.

Lidar, along with complimentary remote sensing techniques, can help clear a path to becoming a more mineral-independent country. The lidar USGS has been collecting through its 3D Elevation Program (3DEP) has provided numerous benefits equating to significant return on investment. Utilizing 3DEP lidar to map our country's critical mineral resources is yet another example of the importance of this program in helping our nation reduce dependence on foreign entities for these critical resources.

Michael Meiser is a Geospatial Project Manager for Woolpert who leads many of the firm's federal lidar projects. Meiser has presented at several industry related conferences including multiple presentations at the International Lidar Mapping Forum (ILMF). Additionally, he has also presented to the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) as a lidar QA/QC expert. He holds certification as a Certified Mapping Scientist-Lidar and is a Project Management Professional (PMP).

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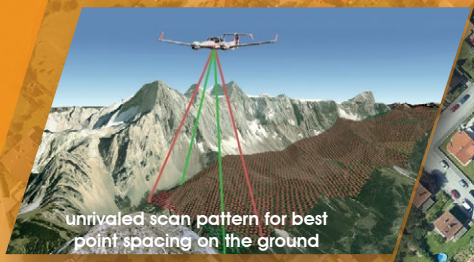
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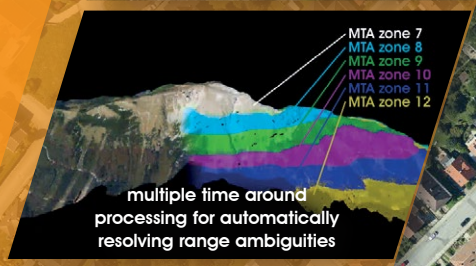

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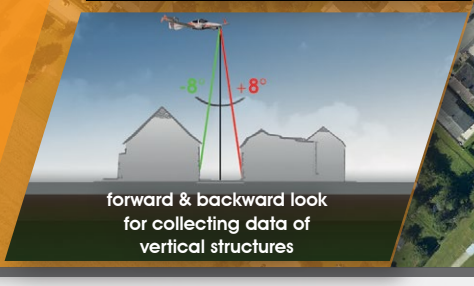

forward & backward look for collecting data of vertical structures

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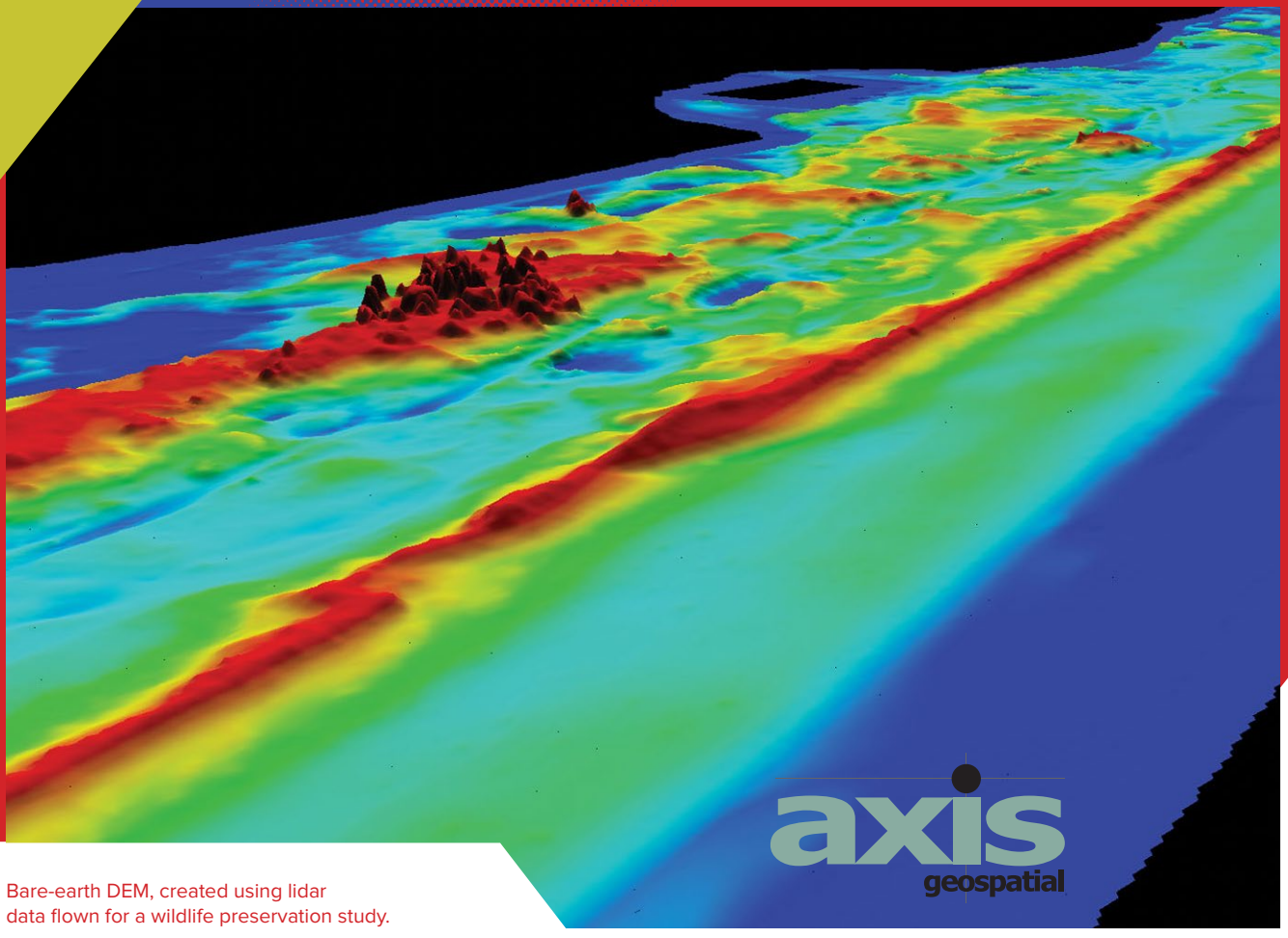


Bare-earth DEM, created using lidar data flown for a wildlife preservation study.

AXIS GeoSpatial leans on lidar to sharpen competitive edge

High-definition lidar finds favor with discriminating customers

BY VICTORIA MIELE

Changes in technology are a frequent occurrence in today's geospatial services world. Companies utilizing these technologies find themselves striving to stay ahead of the curve. The need to be the best and brightest in the industry to stay competitive and be considered as a leading expert in the field is met by organizations who not only deploy the best in technology but employ the best of people.

One of the companies which is successfully navigating the field and providing the highest in quality technology, services, and support for its end users is AXIS GeoSpatial. AXIS relies on its core values of honesty, integrity, accountability, reliability, respectfulness, and teamwork, to govern the way in which it conducts business and ensures they are truly reflected in everything it does.

Figure 1: AXIS headquarters in Easton, Maryland. AXIS moved to Mary's Ct. in Easton in 2017 to meet the space requirements of its growing team and technological investments.

AXIS GeoSpatial Companies

Headquartered in Easton, Maryland (**Figure 1**) with additional locations in Colorado, Delaware, Florida and Virginia, AXIS GeoSpatial employs over 60 individuals with aggressive plans to hire for an additional 10-20 positions during 2019. Founded in 2001 by Justin Lahman and Dave Rorrer, AXIS GeoSpatial[1] has been employing innovative remote sensing and measurement technologies to capture geospatial data for integration into civil engineering, land surveying and GIS applications for the past 18 years.

Its sister company for aerial acquisition services, AXIS GeoAviation, was established in 2012 with operating locations in Easton, Maryland and Ormond Beach, Florida, and 15 employees. AXIS GeoSpatial's Southeast operating unit is a group formerly known as MRG GEO Inc. and based in Ormond Beach, which was acquired in October 2018. Both organizations fall under the "AXIS GeoSpatial Companies" brand and are helping to expand AXIS's reach throughout the United States.

Important team members who ensure that their customers are receiving the most innovative solutions for their projects include Justin Lahman, Barry Gleissner, Allan Blades, Dave Rorrer (**Figure 2**) and Derik Callaway.

Lahman, CEO, AXIS GeoSpatial and AXIS GeoAviation, brings twenty-eight years of geospatial industry experience with him, having managed projects to nearly every state within the domestic United States, as well as internationally. His varied involvement in the geospatial industry, with project experience consisting of photogrammetry, remote sensing, GIS, cadaster, and several other mapping sciences, brings a wealth of knowledge and skill to his clients and end users that showcases the diversity of work AXIS is doing for them. Gleissner, Director of Surveying & Mapping at AXIS GeoSpatial, has 40 years of experience in land surveying and mapping. Holding PLS licensure in Delaware and New Jersey, Gleissner directs the day-to-day operations of AXIS' Surveying and Mapping department. Blades, Vice President of Sales and Marketing at AXIS GeoSpatial, is responsible for the daily

1 More detail is available at www.axisgeospatial.com.

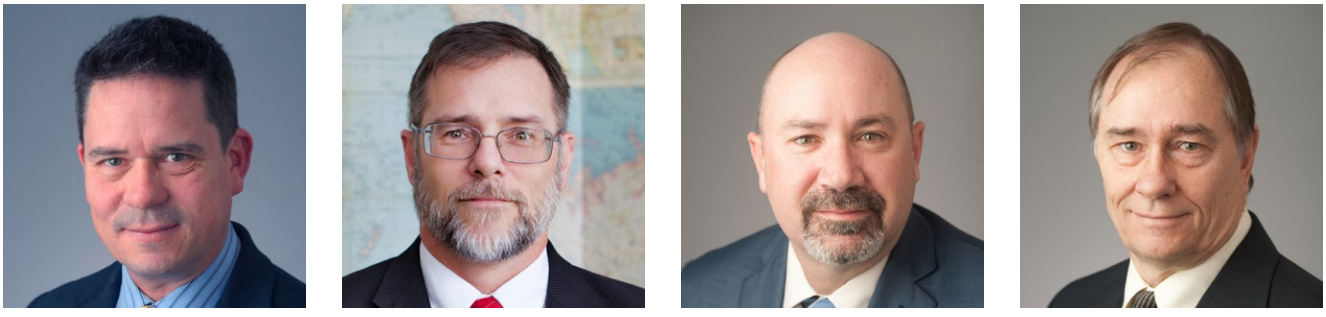


Figure 2: AXIS principals (left to right) Justin Lahman, Barry Gleissner, Allan Blades and Dave Rorrer.

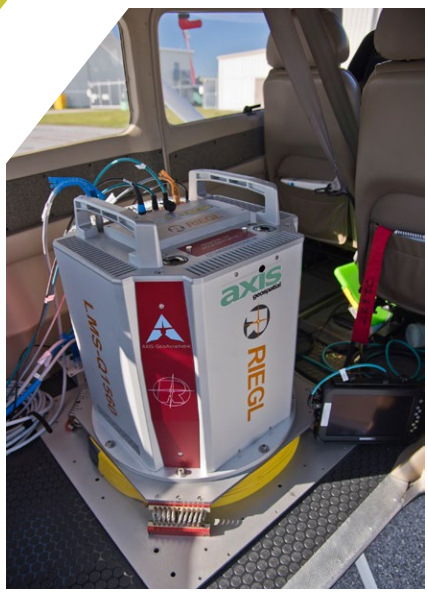


Figure 3: *REIGL* LMS-Q1560 lidar sensor mounted in the company's Piper Navajo aircraft (left) and *REIGL* LMS-Q1560 lidar sensor mounted in Vulcan Air p68C (middle) and Vexcel UltraCam Eagle F100 (right).

activities of the Sales and Marketing department, providing leadership in developing people and project teams that achieve results for stakeholders. Blades has more than 24 years of experience in geospatial acquisition and production services and more than 16 within the DoD/Intelligence community, achieving multiple successes in delivering results for a variety of federal, state, local, and private customers. Callaway, Operations Manager at AXIS GeoAviation, has over 20 years of mapping expertise and project management experience, and manages the aviation team's daily activities and ever-changing schedule to achieve optimal efficiency.

Some of the services offered by the organization include airborne lidar acquisition and processing, ground survey support, landscape and terrain modeling, topographic mapping, planimetric mapping, ortho imagery, and UAS services. These services and projects require cutting-edge technology to acquire, capture, process, and deliver superior data to clients and end users.

Leading the way with lidar

To accomplish and deliver the high-density, high-accuracy projects that its end users need, AXIS purchased its first *RIEGL* lidar system in 2011. *RIEGL*'s density, precision and accuracy were so impressive that AXIS was able to develop an approach to design-scale mapping applications whereby the lidar accuracy rivaled field surveyed data.

Owing to it successes with applying *RIEGL* lidar technology to multiple engineering and surveying applications, AXIS has continued to make significant investments by adding further *RIEGL* sensors to its line-up. Having years of extensive research and development in this technology and its application to design-scale mapping, AXIS has yet to find another commercially available lidar sensor which provides similar density, precision and accuracy.

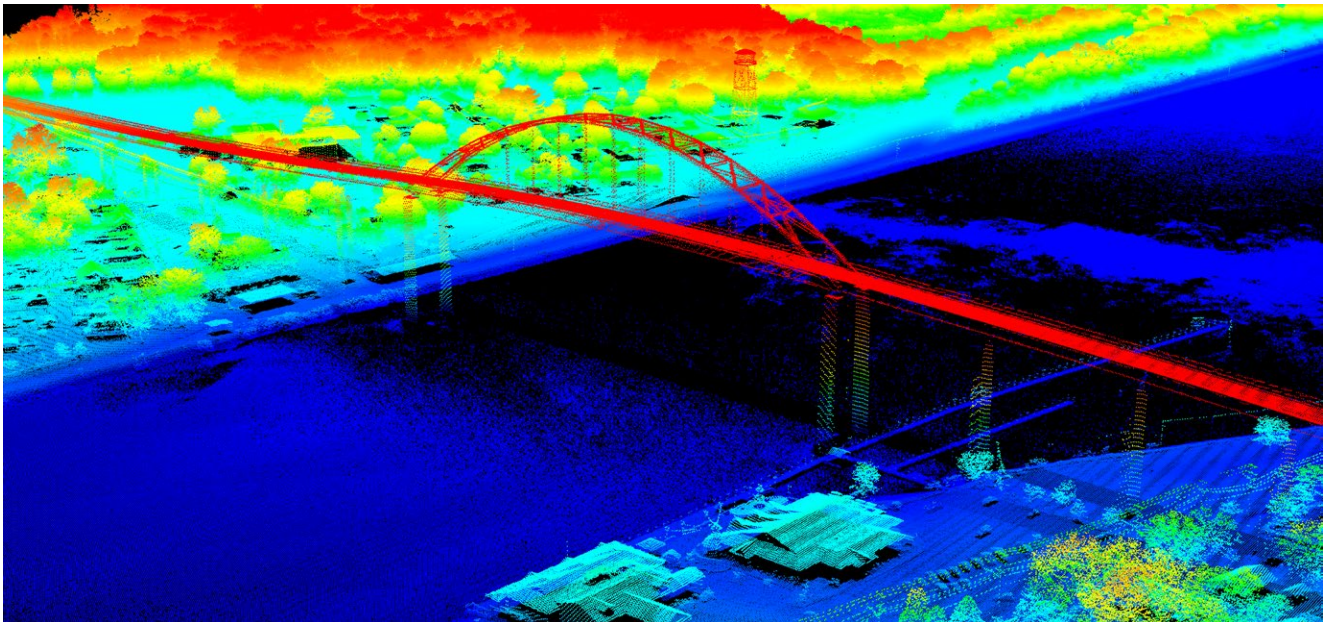
Commented Lahman, "We at AXIS see lidar as a rapidly evolving technology trend that will transform the way in which civil engineers, architects, infrastructure managers, and GIS professionals plan and design solutions for tomorrow's geospatial needs. Our latest expansion and investments in *RIEGL* sensors are based on our predictions of

Figure 4: The AXIS fleet, from top to bottom—single-engine Cessna 206H, twin-engine Vulcan Air p68C (the newest addition), and one twin-engine Piper Navajo.

the innovations that will redefine the scope of work in tomorrow's surveying, engineering and geospatial markets."

The sensors AXIS currently employs are the *RIEGL* LMS-Q1560 full waveform digitizing, dual channel airborne lidar scanning system, two *RIEGL* VQ-1560i dual channel waveform processing airborne lidar scanning systems, and the UltraCam Eagle F100 digital aerial camera (**Figure 3**). *RIEGL* sensors allow lidar and imagery to be captured in a single flight, saving AXIS time and reducing costs for the client. The company's team can provide all Quality Levels of lidar data (QL1, QL2 and QL3) in addition to Hi-Definition LiDAR (HD-LiDAR, a term coined by AXIS GeoSpatial), in which the datasets are suitable for design-scale engineering at 40 points per square meter or more. AXIS utilizes Cessna 206H, Vulcan Air P68C and one Piper Navajo aircraft (**Figure 4**) to ensure that it is providing the best solution from ground to cloud for its client base. These aircraft were chosen specifically for their load carrying capacity, rough field landing ability and low speed performance characteristics, as well as reasonably high cruising speed. The aircraft are specially configured and capable of carrying the *RIEGL* systems, pilot, system operator/pilot and a law enforcement officer (when in restricted airspace) without compromising the performance or safety of the lidar system being flown. The aircraft are staffed by two pilots, who are highly rated and very experienced in the intricacies of flying around complex, and at times, challenging airspace: two sets of eyes and ears can monitor the airspace around the aircraft and maintain a close watch

on communications with air traffic control. This attention to every detail guarantees that AXIS can provide the best in geospatial solutions and adhere to project scope and schedule for a multitude of industries.



Project experience

Given the company's vast wealth of experience, the projects that it has performed showcase the professional work and knowledge shared within the organization. AXIS has performed state DOT work for New Jersey, Maryland, Virginia, Delaware and Florida (**Figure 5**). The level of accuracy in the data provided to the client is so attractive that some state agencies have begun specifically requesting "HD-LiDAR" in their RFPs.

AXIS has mapped several airports using HD-LiDAR technology to provide data for land use/land cover classification of runways, buildings, parking lots and roads (**Figure 6**). AXIS has provided impervious surface models for

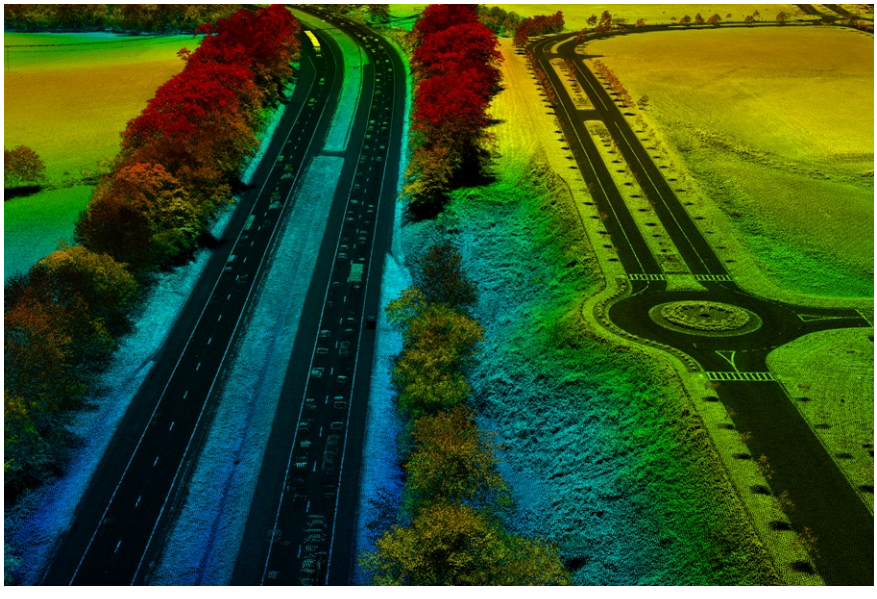


Figure 5: Lidar point-cloud data collected for state DOT projects.

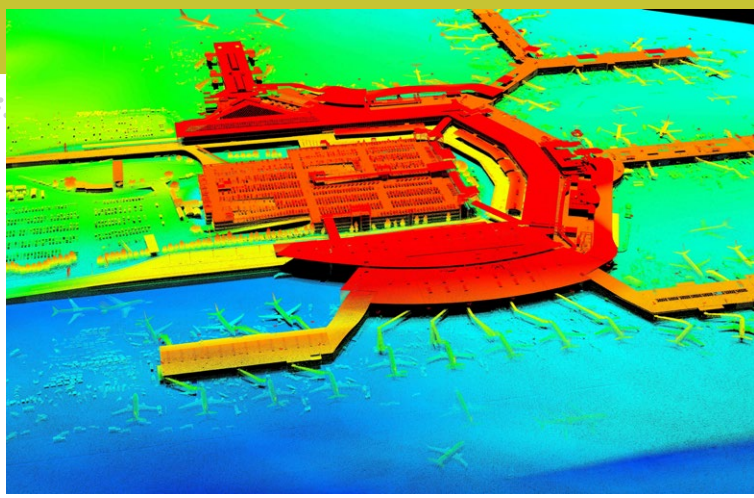


Figure 6: Colorized point cloud of an airport terminal (left) was collected for a FAA 18C obstruction analysis. This view is a combination of the lidar data plus the imagery collected on the same flight. The lidar elevation view of the same airport terminal is shown on the right.

elevation to address drainage concerns in areas prone to flooding that affect airport operations. HD-LiDAR is also excellent for identifying runway surface conditions that may become problematic. Additionally, FAA 18C obstruction analysis can easily be completed using HD-LiDAR data to identify tree tops, buildings and antennae that may pose a risk to traffic in the area. Furthermore, AXIS has used HD-LiDAR to map sites for environmental studies, including wildlife habitat preservation, stream restoration, and watershed and coastline studies (**Figure 7**).

These projects are examples of the superb work that AXIS GeoSpatial has provided both to its end users and to the industry. Working diligently every day to maintain its status as a championship quality team of geospatial data professionals, providing innovative and reliable solutions to multiple industries while achieving the highest in quality and results, AXIS delivers this promise through commitment and integrity. Its focus on delivering exceptional customer service shows how it is revered as a technology leader not only in the industry but also within its community, staying ahead of the curve and establishing itself as the HD-LiDAR leader.

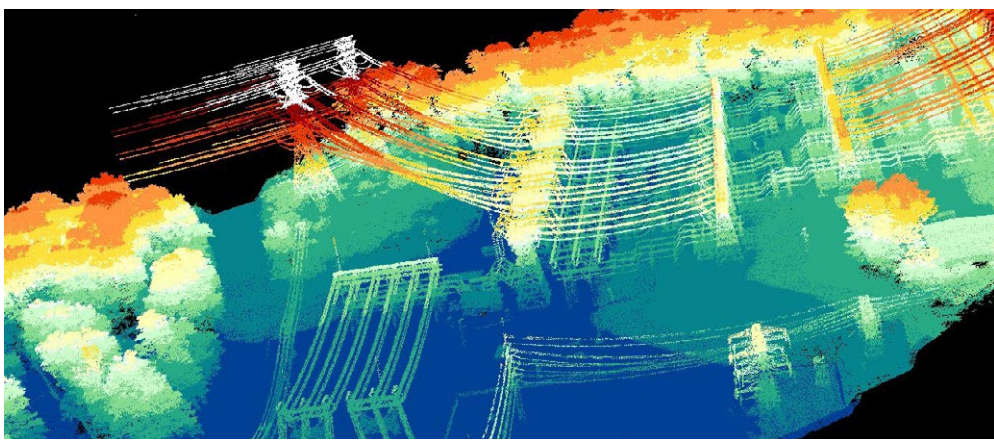
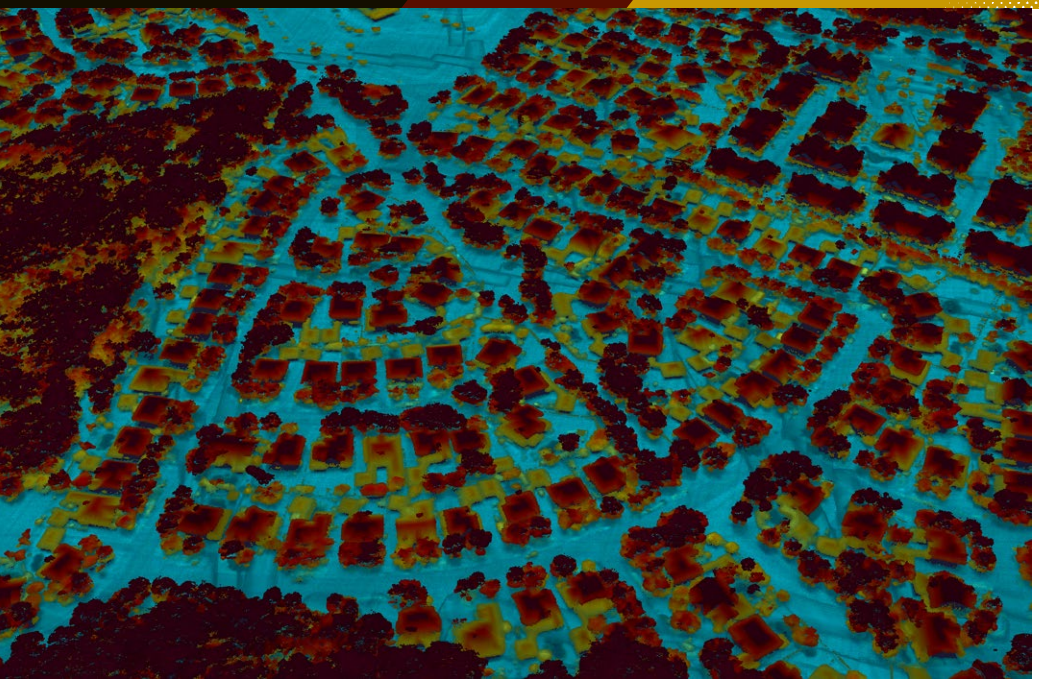
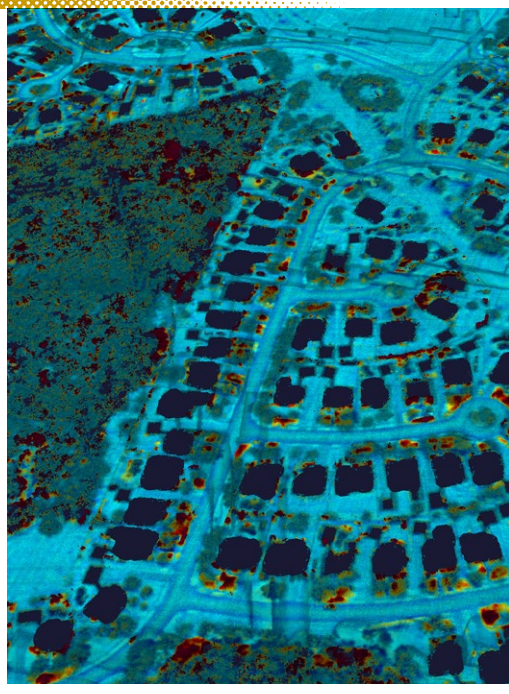


Figure 7: Further applications of HD-LiDAR (from left to right) lidar point-cloud image of a stretch of beach in South Carolina captured for a shoreline study project; lidar point-cloud image of a marsh and marina for a watershed study; raw lidar data collected for a transmission line mapping project.

Victoria Miele is public relations manager for AXIS GeoSpatial Companies, headquartered in Easton, Maryland. Maintaining responsibility for the company's internal and external marketing communications including print, online, social media and trade show marketing, Victoria brings to AXIS 15 years of B2B marketing experience. She holds a BS in business administration and an MBA from Salisbury University.

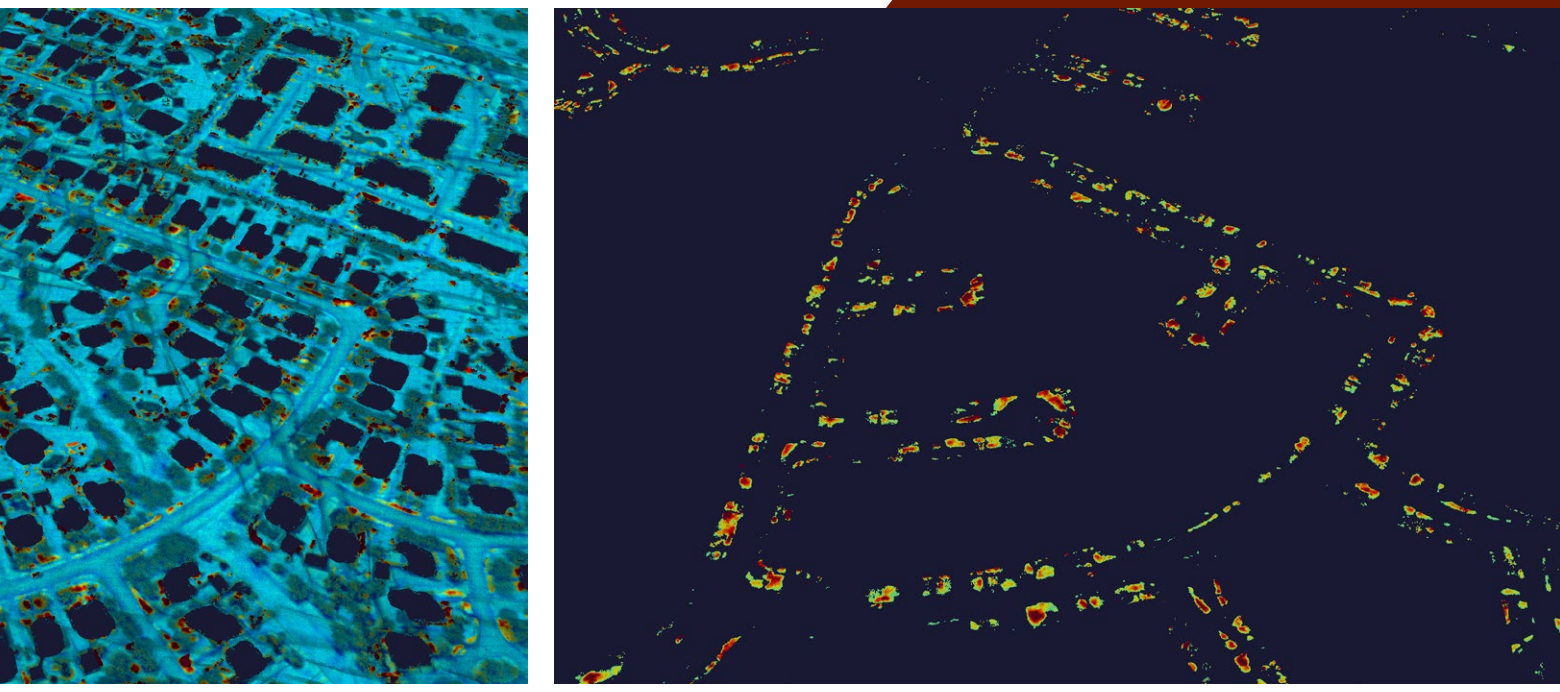




How lidar could transform disaster recovery

MIT Lincoln Laboratory assists FEMA with damage assessment

BY KYLIE FOY



After digitally defoliating and filtering out objects such as houses in the 3D point-cloud image of the Windmill Bluff Lane neighborhood outside of Houston, Texas, Lincoln Laboratory applied novel algorithms to identify and estimate the volumes of debris piles. The volumes were a 95 percent match to the volumes that ground surveyors manually estimated.

MIT Lincoln Laboratory is collecting robust post-disaster lidar datasets and applying advanced algorithms to these data to help FEMA assess damage. The technology could soon be the basis for efficient, data-driven emergency management.

Windmill Bluff Lane looked very much like hundreds of other streets in the suburbs of Houston, Texas, days after Hurricane Harvey hit in 2017. Heaps of sodden furniture, wallboard, and possessions pulled out from each flooded home sat curbside.

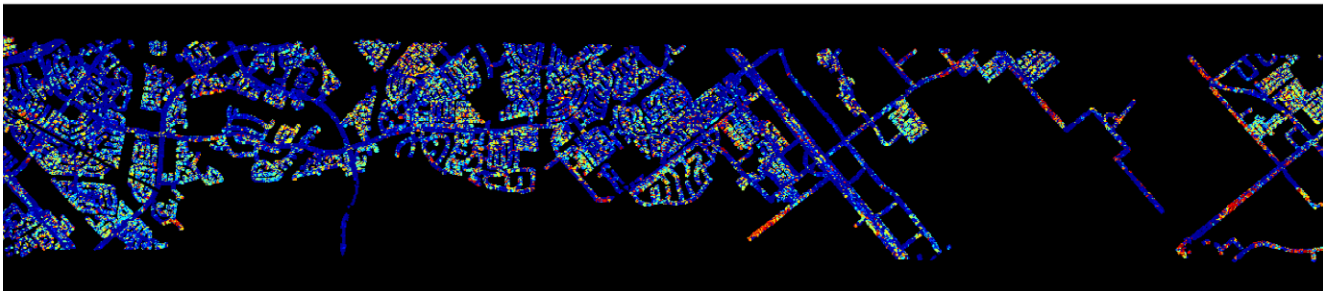
There, the debris was being inspected by the U.S. Army Corps of Engineers (USACE), who manually estimate the volume of each pile and share these estimates with FEMA to inform emergency response decisions. In the midst of assessing damage to public infrastructure, housing, roads, power, and more, the task is time consuming and often results in inaccurate estimates.

Windmill Bluff Lane was different, however, because USACE was not inspecting the curbside debris alone. MIT Lincoln Laboratory was collecting 3D Geiger-mode lidar data over the area and using advanced algorithms to estimate the total volume of debris there. It was the laboratory's first demonstration of how lidar paired with new algorithms could be used to quantify debris after a hurricane.

"We want this type of lidar and analytics to become established tools for disaster relief," said John Aldridge, a leader of the Humanitarian Assistance and Disaster Relief (HADR) Systems Group at MIT Lincoln Laboratory. He's part of the team at the federally funded research and development center that has been developing lidar techniques and advanced algorithms to speed up and simplify tasks of hurricane recovery.

Since its first mission over Houston, the team has imaged thousands of square miles, including all of Puerto Rico and much of North and South Carolina, which were impacted by Hurricanes Harvey, Maria, and Florence. The team is now working with FEMA to integrate lidar and other remote sensing technologies into the agency's workflow. "We think it could be transformative to the way that disaster recovery tasks are done," Aldridge said.

The Windmill Bluff Lane point-cloud is a small subset of this point-cloud covering 50 square miles that was generated from a single scan. Analysts applied the same algorithms that automatically identified debris in that neighborhood to the entire dataset; debris is highlighted below.



Rolling out lidar

The lidar that MIT Lincoln Laboratory is using for these disaster-recovery capability demonstrations is called the Airborne Optical Systems Testbed (AOSTB). It was developed to support research and development in advanced optical detection capabilities, particularly Geiger-mode lidar, which was invented at Lincoln Laboratory more than two decades ago. The AOSTB uses Geiger-mode avalanche photodiode arrays to capture high-resolution, wide-area 3D lidar images.

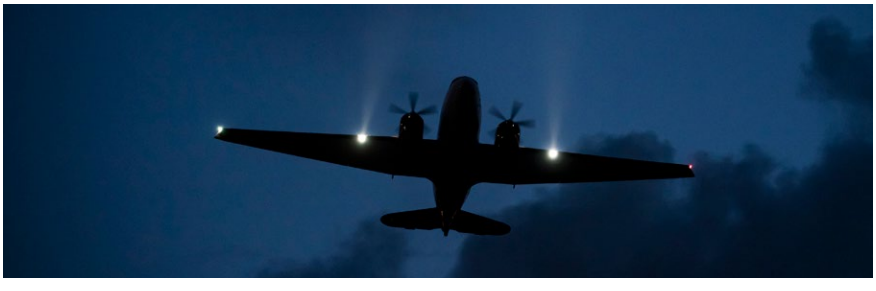
"The lab invented a special kind of detecting array that can make 650 million measurements a second, and it can measure the smallest measure of energy—a single photon," said Jalal Khan, who leads the Active Optical Systems Group that developed the AOSTB.

The resolution the team has targeted is 25 centimeters, balancing a resolution high enough to make out fine scene details with a coverage rate that allows them to image large areas rapidly. "We're imaging swaths about 600 meters wide going 150 knots," said Dale Fried, the CEO of 3DEO, an MIT Lincoln Laboratory spinoff company specializing in Geiger-mode lidar that worked alongside the team to collect the lidar data.

As the lidar is flown, the system uses advanced processing algorithms to generate a preliminary 3D point-cloud onboard the aircraft. To address the large volumes of data, the onboard processing concentrates on regions of interest by finding the digital terrain surface and cropping to data near the ground. This processing allows the flight team to know the sensor is working well in flight, and is then the starting point to interpreting the collected 3D scene.

Proving grounds in Houston

The ultimate goal of the lidar work is to automate the process of answering important questions that FEMA faces after a disaster. Which roads are in need of repair? To what extent is critical infrastructure damaged? Where is



The BT-67 aircraft takes off for a nighttime sortie above Puerto Rico.

Many hillside roads in Puerto Rico were eroded by landslides after Hurricane Maria. Lidar data is being used to measure these elevation drops precisely and plan repairs.
Photo: Glen Cooper.

there debris and how much needs to be cleared?

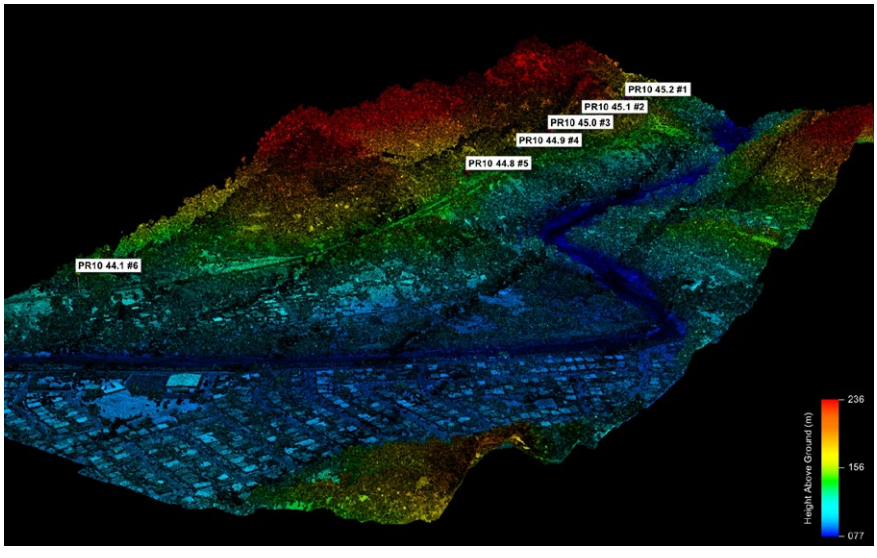
Today, remote sensing is used to help FEMA answer some of these questions. Pre-storm and post-storm satellite imagery are compared, and aerial photography is taken. But much of this work is still a manual process. Analysts must go through this photography to identify and categorize damage, and it's primarily useful for damage that is obvious and to which there is a clear line of sight—a demolished building out in the open, for example, and not a damaged road covered with trees. In most cases, observations will still have to be confirmed with ground-level assessments that require crews on foot using tape measures, taking more pictures, and documenting findings.

"If I look at a photo, how can I tell definitively if something is a hole in the road or if it's a shadow? You need 3D data to answer questions specifically. And to get that to every square mile, you either need an army of people, which is possible but takes a long time, or you can use lidar and an army of computers using machine learning to find answers quickly. That's what we're aiming to do," Khan said.

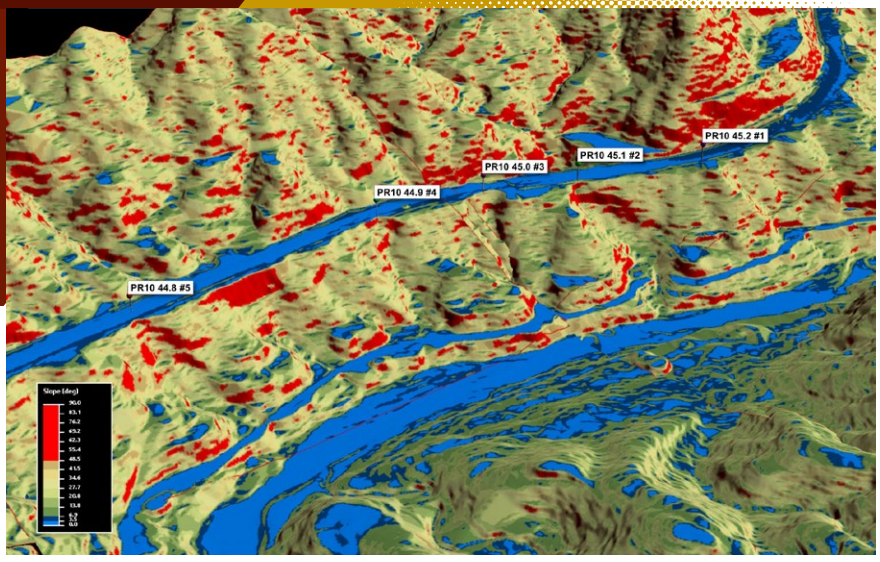
Prior to Hurricane Harvey, the laboratory had conducted experiments with the AOSTB over a mock debris field to understand how the lidar data could be analyzed usefully and efficiently. Given the immense amount of debris left by Harvey (an estimated eight million cubic yards of debris would be picked up in Houston alone[1]), Lincoln Laboratory volunteered to attempt debris measurements to support FEMA's Public Assistance Program, which provides grants to state, local, tribal, and territorial governments for debris removal, emergency protective measures, and restoration of public infrastructure.

The lidar system's ability to see beneath the tree canopy was a key asset, since many of the streets scanned

1 https://www.nytimes.com/2017/09/06/us/garbage-harvey-removal.html.



This product shows a 3D point-cloud image of an area in Utuado, Puerto Rico, color-coded by altitude above sea level. Several points of interest along a roadway identified by FEMA as needing closer inspection are labeled.



Applying slope analysis indicates areas of topographic relief where erosion or landslides may have occurred.

for debris were partially obscured from above by foliage. The AOSTB's rapidly pulsed laser and single-photon sensitivity allow enough light to trickle down through openings in the canopy and back up to the detector to build a practically complete picture of what's underneath. After analysts digitally defoliate the lidar images, the next task is developing algorithms that can make sense of what remains.

"We had to teach ourselves first what debris looks like with lidar to build these algorithms," said Luke Skelly, who worked on the algorithm development team. Traditionally, 3D lidar imagery interpretation has relied on human analysts trained to see patterns in the data. Transitioning this task to algorithms that can accurately discern what objects are in the billions of points in an image is a difficult task.

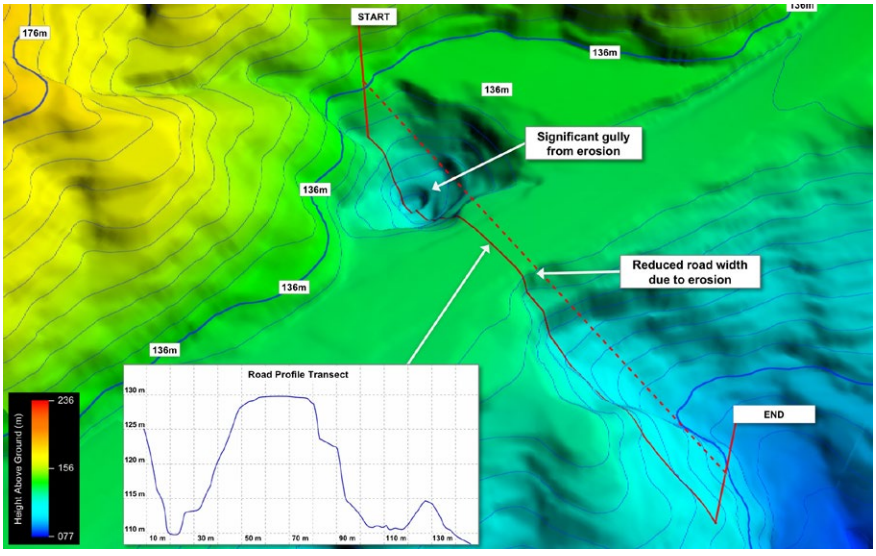
Initial experiments showed success. At Windmill Bluff Lane, the algorithm's debris-volume estimations were a 95 percent match to USACE engineers' in-person estimates. This accuracy built trust to apply the methodology to wider areas.

But each hurricane presents new processing challenges. In Houston, the initial algorithm was tailored for finding debris within fairly standardized neighborhoods. Since then, the team has been adapting these algorithms to different environments. "We are still proving the algorithms out, but the foundational data formed the basis for developing these automated algorithms to find debris," Skelly said. "Now, we are extending these algorithms to find other points of interest, like damaged roads, buildings, and power lines."

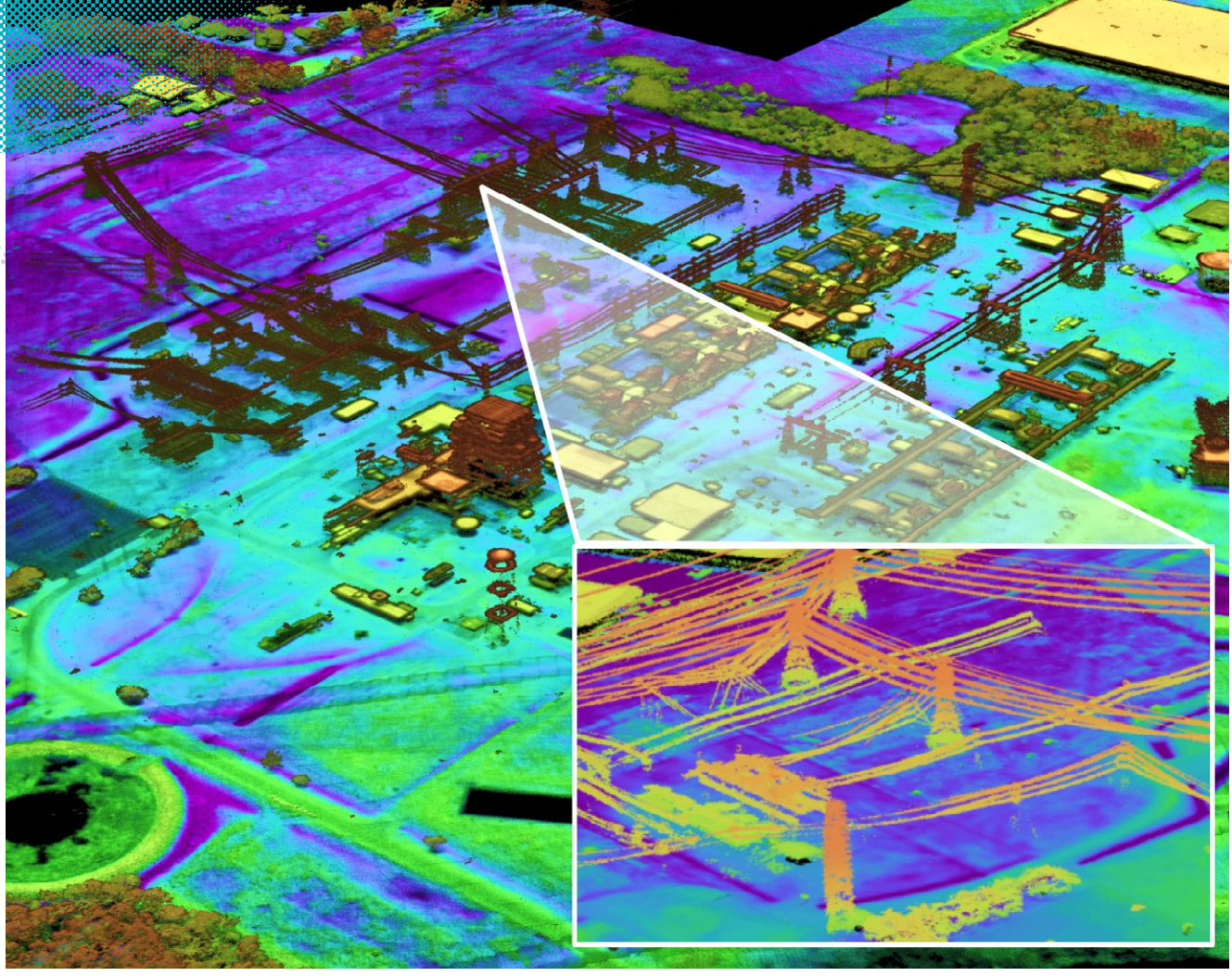
Scaling up

Four weeks after Harvey, Hurricane Maria plowed across Puerto Rico with sustained winds of 155 mph—uprooting trees, downing cell towers, ripping roofs off homes, and cutting electricity to nearly 100 percent of the island.

"We started small, but we quickly had to scale up to address the damage caused by Maria," said Jon Pitts, also a leader of Lincoln Laboratory's HADR Systems Group. "In Harvey, we targeted debris. When we went to Puerto Rico,



A closer view of the digital terrain model at point PR10 45.1 #2 shows road narrowing and the opening of a gully due to erosion. The estimated volume of the gully is 11,234 cubic meters.



A 3D point-cloud image of power facilities near Houston, Texas, is used to identify damage to utility lines and flooding near the plant.

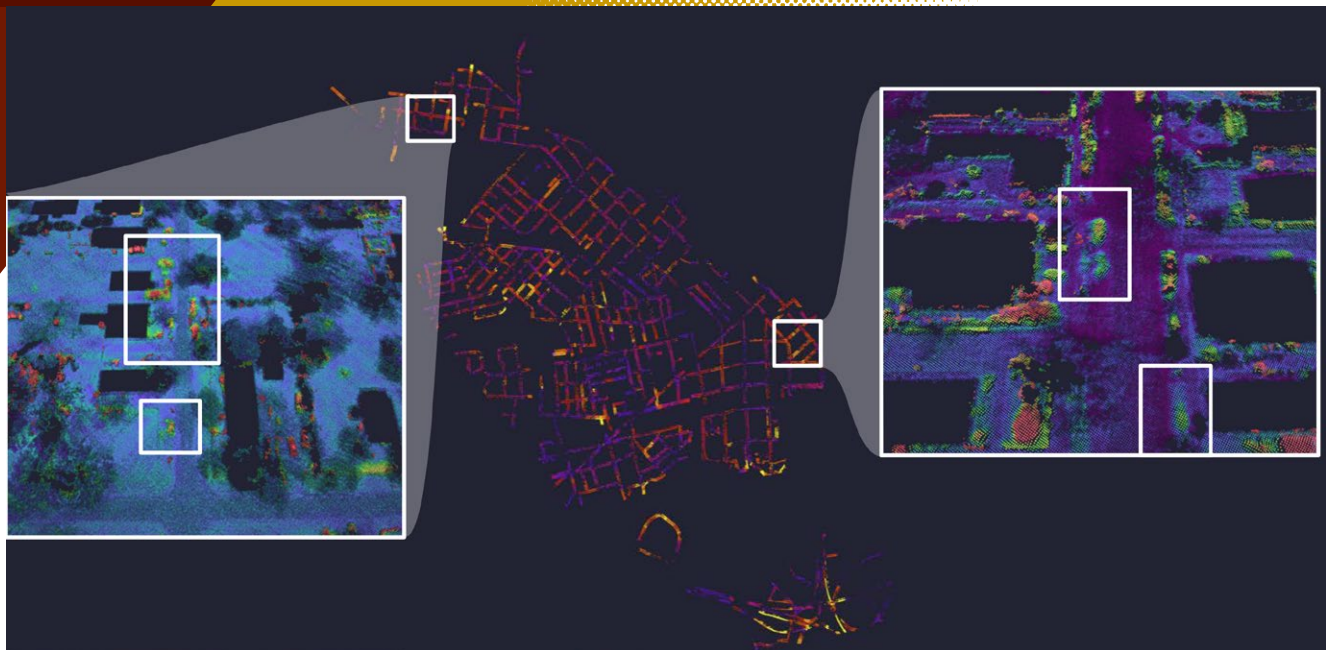
it was about wide area coverage and building a rich dataset that could be analyzed many different ways."

The team traveled to Puerto Rico in the spring of 2018, installing the AOSTB on a leased BT-67, a long-endurance aircraft capable of eight-hour missions. They mapped the 3,500 square miles of Puerto Rico and the islands of Vieques and Culebra over the course of 23 flights. Then, the analysis began.

Damage still needed to be assessed months after Maria, especially to roads in mountainous regions. Laboratory analysts supported FEMA's efforts by performing virtual site inspections on specific roads in the point-cloud map and reporting what they found. For example, they could determine the magnitude of an elevation drop as a result of a landslide or the volume of a washout in a road. At a minimum, this process can augment the manual step of visiting the site to determine how much material is needed to repair damage and how much money will need to be allocated to the repair; at a future stage, it could even cut out the need for this step.

The laboratory also applied its lidar research after Hurricane Florence's washout over the Carolinas in September 2018. After mapping hundreds of square miles along the coastline and river-hugging bands inland, Lincoln Laboratory analysts virtually inspected areas in the point-cloud map that had been reported to FEMA as being flooded. Because the lidar's laser beam does not reflect as well off of water as the ground, flooded areas were represented in the point cloud model as black (no data), making flood waters visually straightforward for analysts to see, especially after the images are digitally defoliated. This information can help officials quickly determine if critical infrastructure such as power facilities has been affected, or if there are environmental impacts such as coal ash pits that may have been breached by flood waters. The data collected in North Carolina was also used to improve the debris-finding algorithm and to develop new algorithms for finding roads and road damage.

Inspecting roads in the lidar data has helped MIT work with North Carolina's Department of Transportation (DOT). Since Florence, DOT has requested FEMA's assistance to repair approximately 2500 roads, five percent of which are included in Lincoln Laboratory's lidar dataset. To help FEMA obtain metrics about the extent of these damages, staff have been analyzing these areas in the data and gathering



Debris identified in the point-cloud map of New Bern, North Carolina, is shown in this lidar debris heatmap, colored purple to yellow based on low to high debris density.

3D measurements of damages such as large holes or sections of roadway that washed away. This information can be used to confirm the in-person measurements that DOT obtains.

The team is also thinking of new ways to interpret its lidar data to help FEMA expedite the process of categorizing damages to homes, such as analytics to determine from lidar data if a home has either sustained moderate damage to its roof or walls, has lost its roof entirely, or has been reduced to rubble.

Mapping the future

In Puerto Rico, moving forward means first going back. Besides helping with active recovery, the island-wide dataset is helping officials take stock of what had already been done in the immediate aftermath of the storm. "There was a huge effort just to get electricity up, to build new access roads to reach places. A lot of work was done quickly, and now with lidar, analysts can go backwards to document what has happened," Fried said.

The AOSTB dataset is being compared to a U.S. Geological Survey pre-storm lidar dataset by overlaying the point clouds and using developmental algorithms to detect and highlight changes. "Transportation officials will be able to determine if an engineering study is needed to see if a temporary road will wash out in the next storm," Fried added.

Likewise, if another hurricane strikes, the AOSTB dataset will serve as a baseline to compare with a new dataset. The laboratory's vision is to achieve a workflow efficient enough to allow FEMA to assess which roads they won't be able travel on, which bridges have been washed away, and which areas have been hit hardest by wind damage or flooding as soon as the lidar data are collected.

In preparing for the future, the key is to find out how lidar can be woven more tightly into FEMA's workflow from the start. Today, laboratory staff are embedded at the FEMA Joint Recovery Office in Puerto Rico to accomplish this integration and to train staff there in interpreting the data.

"What we're showing is that lidar complements all of FEMA's efforts and that it can actually provide a framework to build from. It's a virtual model of real life," Aldridge said. "You can think of it like a Christmas tree, where you can start to hang other data you're working with during a disaster—home locations, photos, storm tracking, surge models, power outages, everything."

FEMA is motivated to leverage new technology. Its strategic plan published in November 2018 emphasized the need to do so "to reduce complexity, increase efficiency, and improve outcomes." Aldridge pointed out, however, that compared to the staggering costs of

A street in New Bern, North Carolina, is lined with debris from water-damaged homes after Hurricane Florence.
Photo: Glen Cooper

disasters in the United States ($306 billion in 2017 from earthquakes, hurricanes, and wildfires[2]), government investment in research and development for disaster relief technology is relatively low. "In my opinion, we as a country can't afford to not invest in technologies like these," he said, "especially as extreme weather events are on the rise." A 2018 NOAA analysis concluded that the global proportion of tropical cyclones that reach Category 4 and 5 levels will likely increase over the 21st century, and sea-level rise is causing higher storm surge levels.

Achieving automation at the scale that the team envisions could significantly cut the costs of assessing damage and planning recovery tasks. What they're working toward is not waiting on cues from FEMA to ask, for example, "What roads in this region are damaged?" but to be able to proactively tell FEMA that their algorithms have detected, say, 100 roads at specific locations that are in need of repair.

Getting to that level of automation is "a worthy endeavor," Pitts said, "and it's going to be an exciting research road to get there." Ultimately, he wants lidar to be a national, if not global, capability that responders and emergency managers can access easily. "Gaining awareness of what's going on immediately after a disaster changes the dynamics of disaster relief and all of the factors involved in saving time, money, and lives," he added.

When giving briefings about this lidar work, Pitts plays a movie that the team created from the imagery. The viewer is flown through the 3D lidar landscape, soaring above the trees in Puerto Rico and down to the ground, around collapsed buildings and roads devoured by landslide. It is a striking way to grasp the destruction that has occurred there. It is also a testament to lidar's ability to deliver what is needed most amid the chaos of disaster: clarity.

Kylie Foy is a science writer at MIT Lincoln Laboratory.

Aboard the aircraft, Dale Fried (right) and Jaron Powser begin analyzing the initial data products being generated as the lidar operates.
Photo: Glen Cooper.

2 https://www.ncei.noaa.gov/news/national-climate-201712.

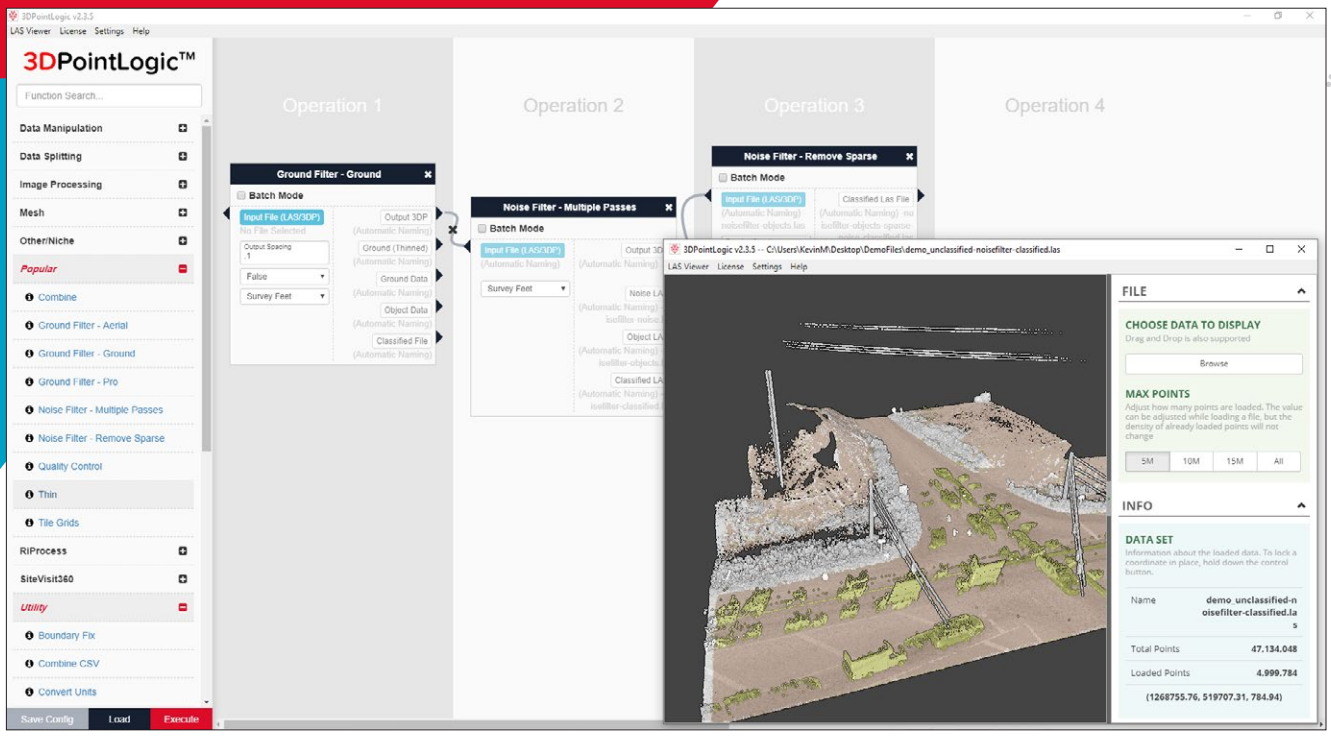


Figure 1: Easy and effective noise filtering and classification with 3DPointLogic.

Need Drove Innovation for Solv3D

Use and sharing of geospatial data now made easy

BY TAMMY PETERSON

Almost a decade ago, a small, forward-thinking surveying and engineering firm based in Calgary, Alberta began collecting large amounts of laser scanning data and quickly realized that there was a lack of suitable tools in the market to assist with the efficient processing of this voluminous point-cloud data, or, even more importantly, allow them to easily visualize and share that data with their clients.

Frustrated by their attempts to accomplish the types of results they desired with existing software offerings, they decided that they would attempt to solve their issues themselves. They began writing code for a set of algorithms to perform various functions that would clean the point-cloud data and transform it into an optimized format for use in creating end products for their customers. They produced a suite of functions akin to a processing "toolkit", which they introduced to a set of other industry practitioners. This peer review enabled

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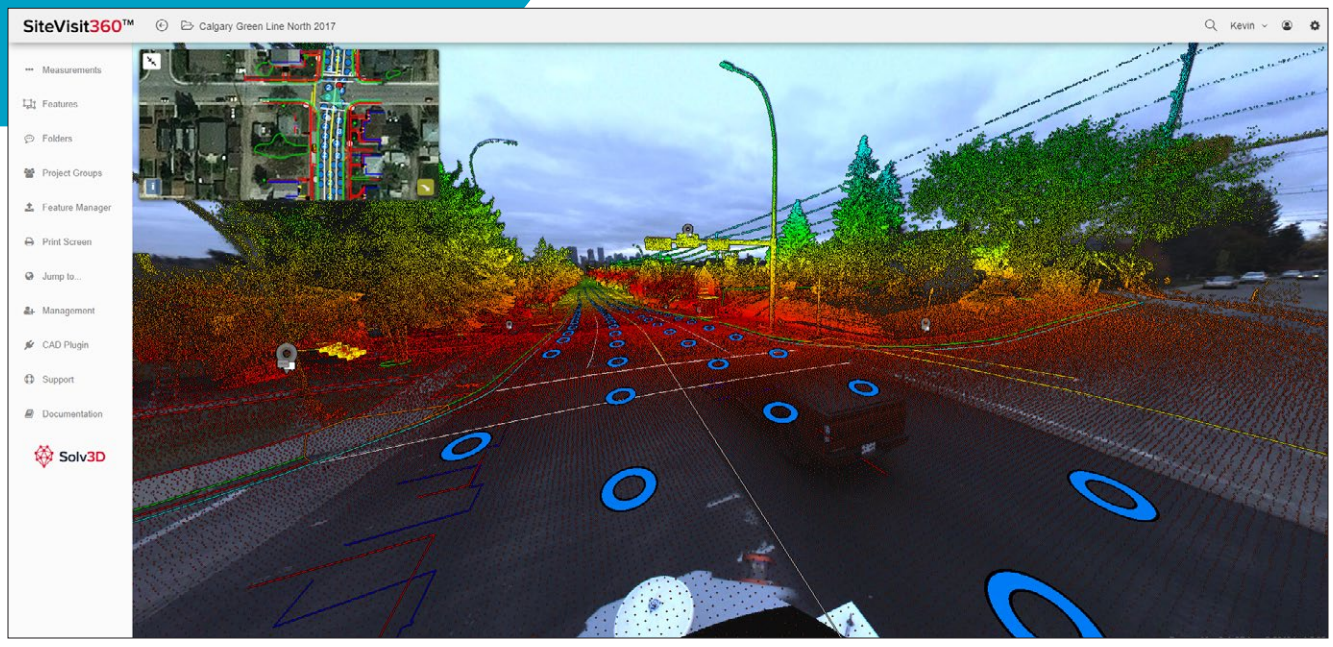


Figure 2: Within a single view, overlay DXF, SHP and KML/KMZ drawings directly on top of imagery and point cloud data in SiteVisit360.

them to realize that they might also be able to help resolve those same issues for others. Encouraged by the feedback from their counterparts, they decided to hire a team of professional software developers to make the products market-ready. Hence Solv3D Inc. was born. Founders Dr. Robert Radovanovic and Chris Tucker were no strangers to starting up businesses: they came from two companies, Sarpi Engineering and Point Geomatics, which merged and became SarPoint Engineering. Solv3D was incubated as part of SarPoint, which continued to operate independently in the survey and engineering services space, until another merger, with McElhanney Geomatics, occurred in September 2017 and Solv3D was spun out to operate wholly as a standalone entity.

2015-2017 was a period of product development at Solv3D, using customer pilots and evaluations to collect feedback that would allow them to flesh out the foundational requirements and prepare for the commercialization of the products. During this time also, the web-based visualization and collaboration platform was conceived and developed. It allowed users to view any type of point-cloud data with panoramic or planar images, simply, in an internet browser. Not only could those collecting the data show it to their clients, but clients taking delivery of the data were provided with a quick and easy way to quality check it and be able to share it with others in their organization. No special software expertise was required.

Now Solv3D had a full offering—two products that could be used as standalone applications or in tandem to create a simple, intuitive and powerful overall solution. Market introduction began in February 2018 and the products quickly evolved with many new features and functions in direct response to end-user feedback. Tools that are easy to use, don't require super computers and are data-agnostic are key features of the Solv3D product palette. The inherent value of geospatial data is not fully derived until it can be accessed and shared throughout an organization, or by external parties, for multiple purposes. The Solv3D products enable organizations to realize a far greater return on their data investment, by providing tools that not only provide an easy and cost-effective way to optimize point-cloud data, but also extend data sharing and use to all stakeholders.

3DPointLogic™ is a middleware toolkit that enables users quickly and easily to clean and prepare their point-cloud data (**Figure 1**). The application is hardware-agnostic, meaning that the sensor used is irrelevant. Indeed, point clouds from varied sources and hardware brands can be combined into a single point cloud. This allows users to gain efficiencies in processing all the data from a project as a single file versus

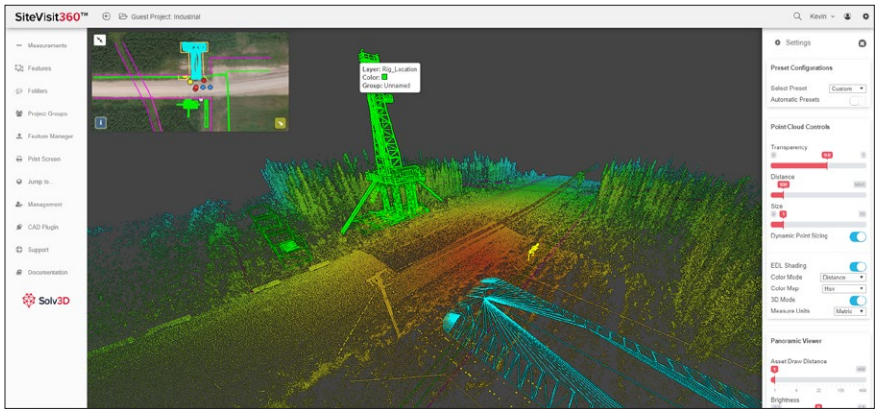


Figure 3: Choose to work completely in 3D mode while still being able to utilize model data within the same single scene view.

having to run each dataset through a proprietary application and trying to combine them *post hoc*.

SiteVisit360™ Geospatial Collaboration Platform is a browser-based application in which a myriad of datasets can be merged together to provide wholistic views and garner situational awareness of projects, assets and areas of interest (AOIs)—regardless of a user's geographic location or level of software expertise (**Figure 2**). Collaboration is fostered within the application through several interactive tools, controlled and customizable by the account administrator (**Figures 3 and 4**). Users are able to easily work together on projects or in managing their assets. Measurements can be taken, annotations made and geolocated tags attached to assets and AOIs to connect to existing information. Users can also record and communicate new information, creating a living system of record. Only an internet browser is required, so the engagement of all stakeholders is far more easily achieved. For example, a large construction and engineering firm currently uses the application to hold their weekly project status meetings. They meet virtually, but are able to visualize, mark-up and record comments on the coming week's action items within the system. The project foreman is then able to access these directives and annotations, while on site.

The announcement of the Esri and AutoDesk partnership in 2017 started a trend towards bringing together GIS and CAD, spatially based disciplines that previously had been rather disparate. SiteVisit360 is the visualization tool that provides a bridge for users from both sides to be able to work together in a truly collaborative manner. AutoCAD users can load their DXF models and GIS users can import shapefiles, ArcGIS Online Maps, or other web services—all within the same scene and all accessible using only an internet browser.

The target audiences and applications for these products are very diverse; from estimation and planning, for example, to quality control, quality assurance, safety analysis and risk assessment. Solv3D assists clients in using technology to provide them a way of doing their job more safely, effectively and efficiently. Although the applications will continue to evolve, SiteVisit360 and 3DPointLogic are already making the utilization of point clouds and other geospatial datasets much easier: from anywhere, by anyone, at any time.

Tammy Peterson is Vice President of Marketing and Sales at Solv3D Inc. Her professional experience spans more than 20 years in the areas of sales, marketing and channel strategy and development. She has worked in a broad range of industries but entered the geospatial realm in 2007 and worked for over a decade at Valtus Imagery Services (a division of North West Geomatics), managing and building the data-as-a-service business and its sales channel, which would ultimately become the Hexagon Content Program, after North West was acquired by Hexagon in 2014. In December 2017, she joined Solv3D Inc., a Calgary software start-up focused on innovative geospatial software applications.

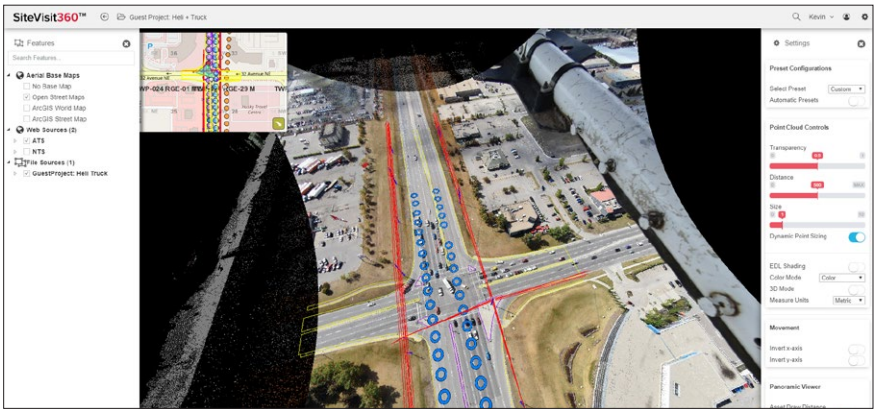
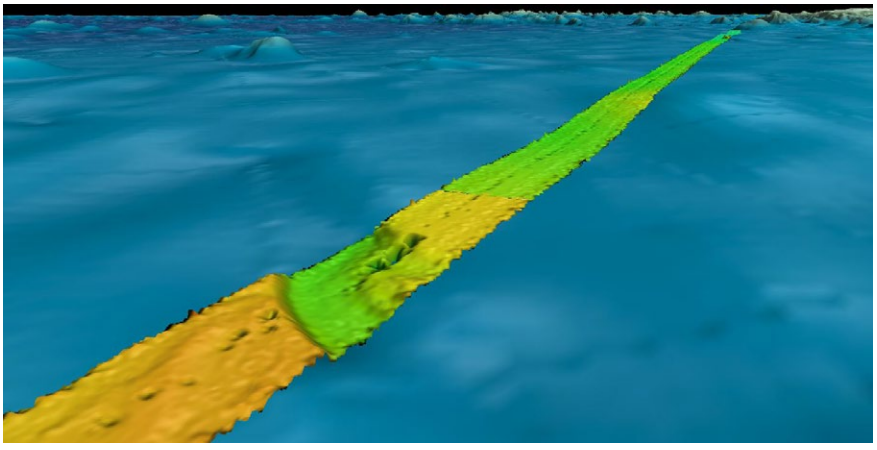


Figure 4: The combinations and uses of various geospatial datasets are limited only by the imagination of the end user.



High-resolution crowdsourced bathymetry data collected by Fugro using multibeam echosounder systems while transiting between project locations.

Fugro Supports Two Ocean Mapping Initiatives with Large Crowd Sourced Bathymetry Contribution

Fugro recently contributed more than 110,000 square kilometres of high-resolution bathymetry data in the North Atlantic Ocean to help improve the quality and coverage of seabed mapping in the region. The dataset, which covers an area the size of Iceland, was delivered to two complementary programs: the Atlantic Ocean Research Alliance (AORA) and The Nippon Foundation-GEBCO Seabed 2030 Project (Seabed 2030).

"As is common across the world's oceans, much of the Atlantic lacks the modern bathymetry data needed to properly understand the seafloor, its resources, and its processes," said David Millar, Fugro's government accounts director in the Americas. "We are proud to help close these data gaps with continued crowd sourced bathymetry data contributions to AORA and Seabed 2030."

AORA was formed under the 2013 Galway Statement on Atlantic Ocean Cooperation between the European Union, the United States of America, and Canada. With a goal of improving knowledge about the Atlantic Ocean to support a prosperous and sustainable blue economy, AORA has identified seabed mapping as a priority area of collaboration.

Seabed 2030 is a global initiative between Japan's Nippon Foundation and the General Bathymetric Chart of the Oceans (GEBCO) to produce a definitive, high-resolution bathymetric map of the entire world's ocean floor by 2030. Currently, less than 20 percent of the oceans are mapped to modern survey standards.

Fugro's approach to crowd sourced bathymetry was developed in 2017 and involves in-transit data collection from multibeam-equipped survey vessels. The company currently deploys the capability from seven ships and ultimately plans to expand the offering across its entire global survey fleet. The most recent datasets were acquired from the *Fugro Discovery* while transiting between Scotland and the United States, and from the *Fugro Searcher* while travelling between Brazil and Canada. Fugro's overall data contributions in the North Atlantic now total approximately 278,000 square kilometres, bringing its global contributions to approximately 450,000 square kilometres. Contributions are expected to increase annually as additional vessels are added to the program.

In disseminating the crowd sourced bathymetry to AORA and the Nippon Foundation-GEBCO Seabed 2030 Project, Fugro coordinates with the International Hydrographic Office's Data Center for Digital Bathymetry. The center is located within the U.S. National Oceanic and Atmospheric Administration's National Center for Environmental Information (NOAA NCEI). Fugro maintains a long and successful working relationship with NOAA, and earlier this year teamed with NCEI to develop a workflow for integrating third party datasets into the Seabed 2030 project database.

Fugro is the world's leading Geo-data specialist, collecting and analysing comprehensive information about the Earth and the structures built upon it. Adopting an integrated approach that incorporates acquisition and analysis of Geo-data and related advice, Fugro provides solutions. With expertise in site characterisation and asset integrity, clients are supported in the safe, sustainable and efficient design, construction and operation of their assets throughout the full lifecycle. Employing approximately 10,000 talented people in 65 countries, Fugro serves clients around the globe, predominantly in the energy and infrastructure industries, both offshore and onshore. In 2018, revenue amounted to EUR 1.7 billion. The company is listed on Euronext Amsterdam.

Phase One Industrial Introduces Three High Performance Lenses for High-Altitude Aerial Photography and Long-Range Aerial and Ground Inspection

The new 300mm AF, 180mm, and 150mm MK II lenses are designed to enhance the versatility and performance of Phase One Industrial's iXM-RS and iXM 150MP to 50MP resolution camera series

Phase One Industrial has expanded its RS and RSM lens offering with three new high performance lenses for high-altitude aerial photography and long-range aerial and ground inspection applications. The 300mm AF, 180mm, and 150mm MK II lenses are designed to enhance the performance and flexibility of Phase One Industrial's iXM-RS and iXM aerial camera series. Each offers precision imagery, taking advantage of the cameras' ultra-high resolution backside-illuminated (BSI) CMOS sensors, to maintain a smaller ground sample distance (GSD) while flying at higher altitudes.

Phase One High-Performance lenses: 300mm AF, 180mm, and 150 MK II. In the foreground: Phase One 300mm AF lens mounted on the Phase One Industrial iXM-RS150F medium-format camera.

Phase One RSM 300mmAF

With the longest focal length in the line-up, this lens offers a 5 cm GSD from 13,000 ft. It fits both iXM and iXM-RS camera models and produces superb image quality by enhancing the cameras' ultra-high resolution BSI CMOS sensors (3.76 µm pixels). The lens is ideal for both high-altitude 2D and 3D mapping and long-range ground inspection. The motorized lens offers a focus range of 10 m to infinity within which a predefined distance can be set remotely. A self-locking mechanism is built in to secure the focus position against vibrations.

- 5 cm GSD from 13,000
- 10 m to infinity focusing range
- f/8 – f/32 aperture range
- 1/2000 sec exposure time
- RS Shutter reliability – 500,000 actuations

Rodenstock RS 180mm

Specified by Phase One and built by Rodenstock Photo Optics, Germany, this lens reaches a 5 cm GSD from 8,000 ft. when used with the iXM-RS150F camera. The lens supports the camera's ultra-high resolution BSI sensor for greater image quality and is integrated with a Phase One RS reliance shutter for speed and reliability. The RS 180mm enhances high-altitude aerial 2D and 3D mapping and improves efficiency in oblique configurations.

- 5 cm GSD from 8,000
- f/6.3 – f/22 aperture range
- 1/2000 sec exposure time
- RS Shutter reliability – 500,000 actuations

Phase One RS 150mm MK II

A 5 cm GSD from 6,500 ft. is achievable with the RS 150mm MK II lens. It complements the iXM-RS150F camera's ultra-high 150-megapixel resolution BSI CMOS sensor for acquiring quality images for high-altitude aerial 2D and 3D mapping.

- 5 cm GSD from 6,500
- f/5.6 – f/22 aperture range
- 1/2500 sec exposure time
- RS Shutter reliability – 500,000 actuations

Every Phase One Industrial lens is rigidly built for robustness against vibrations and shocks to meet RTCA DO160G standards, and is individually tested for performance and high-modulation across the whole image area.

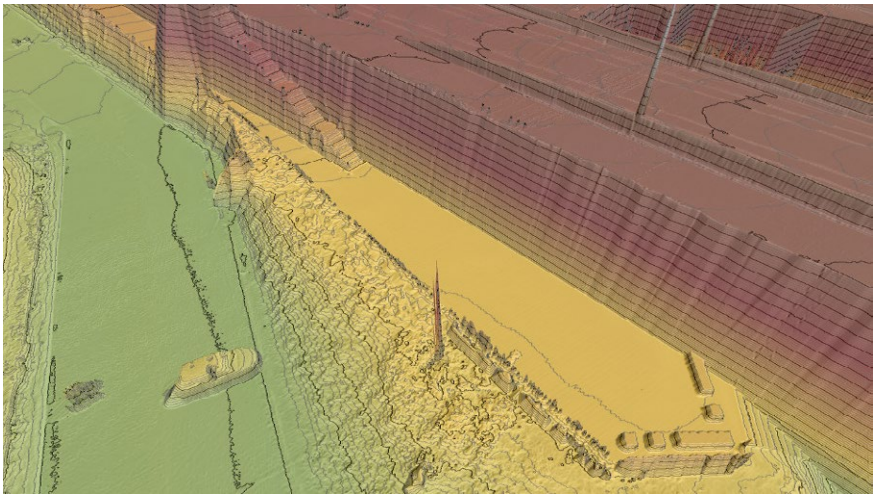
Pricing and Availability

The Phase One RS 150mm MK II is available to order from May 2019. The RSM 300mm AF and RS 180mm lenses are available for pre-ordering and will begin shipping in September 2019. For pricing, please contact: industrial.phaseone.com/contact.aspx

Phase One Industrial is the division of Phase One A/S that researches, develops, and manufactures specialized industrial camera systems and imaging software solutions. The company focuses on specific industry applications such as aerial mapping and surveying, ground and aerial inspection, agriculture, machine vision, and homeland security. For more information, please go to: industrial.phaseone.com

Virtual Surveyor Unveils Terrain Lenses in Drone Mapping Software

Better Understanding of Topography



A Virtual Surveyor Elevation, Hill Shade and Contours lens combination using Stormbee lidar data.

Virtual Surveyor has unveiled Terrain Lenses in Version 6.3 of its popular drone surveying and mapping software. Overlaid on a LiDAR point cloud or orthophoto, the six lenses enhance different aspects of the terrain in 3D to give users a better understanding of the topography in the area they mapped with an unmanned aerial vehicle (UAV).

The Virtual Surveyor package enables professional surveyors to generate accurate topographic end products from drone data five times faster than traditional field work, bridging the gap between UAV photogrammetric processing software and engineering design packages.

"Whether a drone surveyor is generating map products from orthorectified imagery or LiDAR elevation data, our new Terrain Lenses provide richer insights into the topography," said Tom Op 't Eyndt, CEO of Virtual Surveyor nv in Belgium. "Instantly applied with a single click or shortcut, the Lenses can be used alone or together to achieve different effects."

Six Terrain Lenses have been included in Virtual Surveyor 6.3:

- **Hill Shade lens** – Designed mainly for application on a Digital Surface Model created from LiDAR data without an underlying ortho, the Hill Shade lens simulates sun illumination casting shadows on the scene. The result is enhanced 3D perception of hills, valleys and other relief.
- **Contours lens** – This lens creates smooth contours over the terrain. It helps to trace the route water would take as it flows through the terrain. Also, when

Cepton Unveils High Scan Rate, Long-Range SORA-P60L LiDAR for UAVs

New sensor provides industry-leading 400Hz scan rate for UAVs for advanced mapping and surveying

Cepton Technologies, Inc., a provider of 3D LiDAR solutions for automotive, industrial, security and mapping applications, has unveiled the newest product in its SORA family of scanning LiDAR sensors. Released at AUVSI Xponential 2019, the SORA-P60L is purpose-built to deliver long-range, high-resolution imaging for unmanned aerial vehicles (UAVs).

The SORA-P60L stands out with its impressive 400 Hz frame rate, enabling drones to fly faster while maintaining high point cloud density. With a 550 gram payload, the SORA-P60L prolongs UAV flight time allowing more ground to be covered in a single trip. Cepton's unique Micro-Motion Technology (MMT™) faces all lasers downward at all times, providing a uniform point cloud that is over four times denser than other solutions. This, in combination with the high scan rate, makes the SORA-P60L the ideal solution for fixed wing and fast-moving rotary wing UAVs.

"Cepton's SORA-P60L leads the LiDAR industry with its best-in-class point cloud density that provides superior imaging for UAVs. With the affordable price point, long-range capabilities and high frame rate of SORA-P60L, UAVs can capture data faster and build more accurate maps," said Neil Huntingdon, Cepton's VP of Business Development. "SORA-P60L is our first product

cleaning 'noise' from a water body, this lens assists in tracing a boundary at the same level.

- **Transparent lens** – Ideal for areas where topographies change quickly and hide previous states, this lens allows the user to look through one terrain model to see the surface, boundaries or breaklines from a different day.
- **Slope Direction lens** – Designed for better understanding of hydrology, this lens places arrows over the digital surface model to show the direction of water flow throughout the scene.
- **Slope Steepness lens** – When the terrain is too bright or dark in an orthophoto, it can be difficult to detect breaks in the terrain to draw breaklines. This lens colorizes the slopes to highlight breaklines.
- **Elevation lens** – This lens automatically colorizes the terrain so that ground surfaces of the same elevations appear in the same colors, giving the user an easy understanding of the highs and lows of the landscape.

"In addition to the Terrain lenses, Version 6.3 gives users a more stable experience with faster rendering and navigation, even while complex calculations are occurring in the background," said Op 't Eyndt.

Virtual Surveyor users will find several other new or enhanced capabilities in Version 6.3:

- **Copy/Cut/Paste** – Project structure is important, and these functions can be used to move any project item to another layer or to duplicate an existing project item before starting an edit.
- **Split Line Tool** – Commonly used to calculate material volumes in mines and quarries, the new Split Line Tool allows the user to cut out pieces of a boundary drawn around the feature or area to be calculated.
- **Q-Points Algorithm** – The Q-Points Productivity Tool has been improved to capture more detail with fewer points. This tool generates Surfaces or TINs by selecting only the meaningful ground points that define the topography, reducing surface generation time by up to 90 percent.

Current subscribers to Virtual Surveyor will see their software being updated to Version 6.3 automatically.

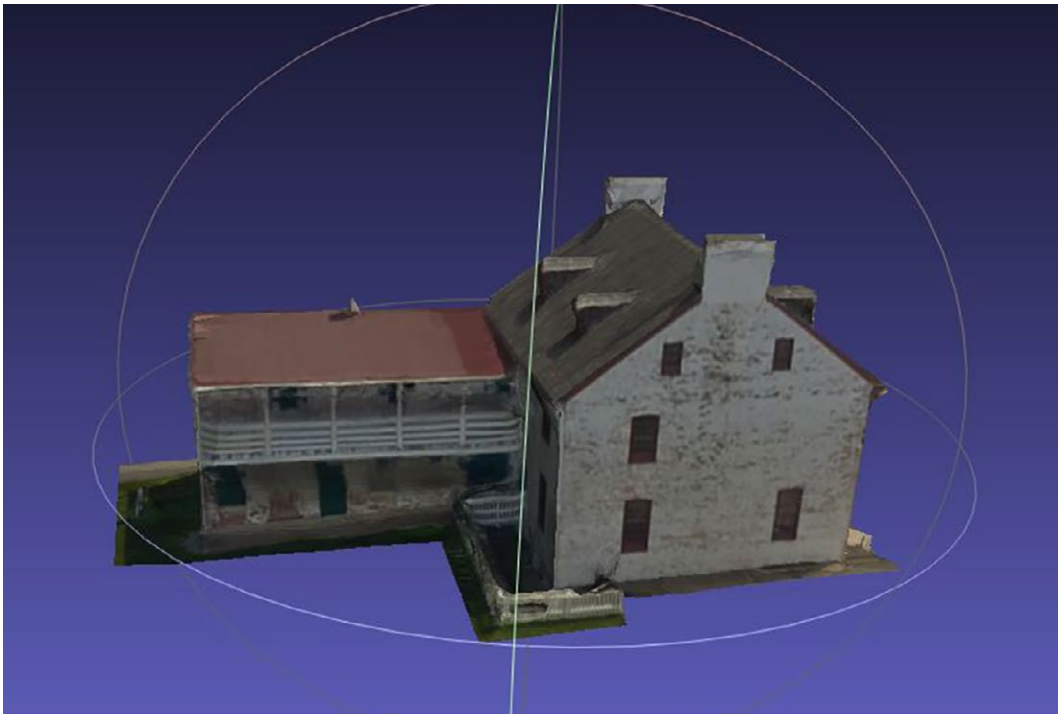
To start a free 14-day trial of Virtual Surveyor, visit virtual-surveyor.com.

Virtual Surveyor software enables professional surveyors to generate accurate topographic end products from drone imagery five times faster than traditional field work. Now used in 61 countries, Virtual Surveyor allows surveyors to create light-weight CAD models from drone data in very short timeframes. In a typical application, the suite takes the orthophotos and digital surface models (DSM) extracted from UAV imagery with photogrammetric software like Pix4D, Photoscan or DJI Terra and generates an interactive virtual environment onscreen where surveyors can select the survey points and breaklines that define topography. Standard topographic outputs from the Virtual Surveyor software are Surfaces or TINs (Triangular Irregular Network), Contours, and Line Surveys. These survey-grade deliverables are ready for direct input into computer aided design (CAD) software packages such as AutoCAD, Civil3D, Magnet Office, Vulcan and BricsCAD. As such, Virtual Surveyor bridges the gap between UAV photogrammetric processing software and engineering design packages.

from the SORA family that we have unveiled this year. We see a lot of opportunities for this unique sensor in other markets and have a number of products in development that will be revealed later this year."

Cepton Technologies, Inc. is a 3D sensing solutions provider shipping next-generation LiDAR products for the automotive, industrial and mapping markets. Founded in 2016 and led by LiDAR and advanced image industry veterans, Cepton has a leadership team that recognizes where the automotive industry and Internet of Things (IoT) market are headed and have deployed four advanced LiDAR solutions that are mapping the future. Cepton LiDAR technology delivers unrivaled detection range and resolution at low cost, to enable perception for the fast growing market for smart machines. For more information, visit.cepton.com.

SORA-P60L



3DML Export to individual models—TerraExplorer 7.1 offers a wide range of options for exporting polygonal areas of a 3DML, e.g., buildings, to individual OBJ models to enable you to easily extract precisely the areas that you need. A point feature layer is also created in the export process that contains the models' positioning information.

Skyline Software Systems Releases TerraExplorer for Desktop 7.1

Skyline Software Systems Inc. announced that it has released TerraExplorer™ for Desktop 7.1 as part of its robust suite of 3D geospatial mapping solutions. This latest update contains enhancements and features that include improved integration with CityBuilder™, more powerful analytics capabilities, and support for VR technology.

The new TerraExplorer release vastly expands its mesh layer capabilities to include greater integration of CityBuilder's 3DML classification tools, which eases incorporation of BIM data and enables quicker editing capabilities for building features and attribute classification. More powerful analytics include a new time swipe tool allowing users to easily see changes taking place over time, and the elevation difference tool highlights changes in elevation or volume. The new volume analysis tool helps speed up analysis of storm damage and debris removal, and the buffer tool allows users to quickly assess buffer/safety zones. VR support is also now available via integration with the Oculus Rift virtual reality system. This integration allows users full immersive experience within Skyline's

> "Our users will be so excited to get the new version of TerraExplorer. With major upgrades in visualizing lidar classification layers, and asset tracking over time along with VR integration, users have even greater resources at hand to immerse themselves in their work."
>
> — Bob Peters, President & CEO

Swipe 3D Mesh Layers—New comparison tool supports enhanced spatial and visual analysis, allowing you to carefully compare between two mesh layers, e.g., to contrast between the state of an area before and after a disaster or visualize changes over time.

actionable 3D environments providing new perspectives and advanced capabilities for data use.

TerraExplorer allows users to view and build realistic 3D visualizations by overlaying the terrain with unlimited data layers, 3D models, virtual objects and more. TerraExplorer Is part of the SkylineGlobe software suite which also includes PhotoMesh™, and TerraBuilder™. This powerful suite of mapping solutions enables an enterprise to build, edit, navigate, query, and analyze realistic 3D environments, and rapidly and efficiently distribute them to users.

Founded in 1997, Skyline Software Systems, Inc. is a leading provider of 3D earth visualization software and services. The company offers a comprehensive platform of applications, tools and services that enable the creation and dissemination of interactive, photo-realistic 3D environments. Skyline has built a "best of breed" set of tools that remain focused on the needs of its customers including flexibility, efficiency and robustness. More information is available at skylineglobe.com and on the Skyline YouTube channel.

New Elevation Difference Tools—New tools analyze the elevation difference between 3D mesh layers or between elevation layers in a defined polygonal area, allowing you to carefully compare between two layers, e.g., to contrast between the state of an area before and after a landslide or volcano, or to evaluate restorative efforts following mining activity.

Named in memory of Dr. Carl Pulfrich of the scientific staff at Carl Zeiss, the Carl Pulfrich Award honours achievements in the fields of photogrammetry, remote sensing and earth imaging.

Leica Geosystems Opens Nominations for Carl Pulfrich Award 2019

Prestigious award honours advancements in the fields of photogrammetry, remote sensing, earth imaging

Leica Geosystems, part of Hexagon, is calling industry-related professionals to submit their nominations for this year's Carl Pulfrich Award, the prestigious industry honour that recognises advancements in the fields of photogrammetry, remote sensing and earth imaging.

Nominees will be considered on the basis of experience, activities in field of photogrammetry and remote sensing, and contributions to the advancement of all aspects of the earth imaging field. Applied work involving hardware systems, software solutions or innovative service activities will also be considered. With the Carl Pulfrich Award, Leica Geosystems continues the tradition of promoting outstanding scientific, application-oriented design and manufacturing ingenuities in the industry.

"Winning the Carl Pulfrich Award puts participants among the best in their field of work. It means they significantly contributed to the photogrammetry, remote sensing and earth imaging fields and their projects have delivered results. We are pleased to support Leica Geosystems in the recognition of these significant contributions," said Prof. Dr.-Ing. Uwe Sörgel, Institute for Photogrammetry, University of Stuttgart and chair of the Carl Pulfrich Award jury.

How to nominate

Nominations can be submitted by email to Carl-Pulfrich-Price@leica-geosystems.com. Closing time for submissions is 15 July 2019 at 5 p.m. CEST. Nominations received after this time and date will not be considered.

Winners will be announced during the award ceremony at the 57th Photogrammetric Week (PhoWo) in Stuttgart, Germany, 10 September 2019.

History of the Carl Pulfrich Award

The biennial award and donation honours the memory of Dr. Carl Pulfrich, a member of the scientific staff at Carl Zeiss from 1890 to 1927. During his tenure, Pulfrich directed the design of the first stereo photogrammetric and surveying instruments from Zeiss.

The Carl Pulfrich Award has gained worldwide recognition. Past winners include Prof. Dr.-Ing. Franz Rottensteiner, winner of the award 2017, and Dr. Christoph Strecha, winner of the award 2015.

For more information about the Carl Pulfrich Award criteria, please visit: leica-geosystems.com/about-us/events/events-overview/2019/carl-pulfrich-award.

Revolutionising the world of measurement and survey for nearly 200 years, Leica Geosystems, part of Hexagon, creates complete solutions for professionals across the planet. Known for premium products and innovative solution development, professionals in a diverse mix of industries, such as aerospace and defence, safety and security, construction, and manufacturing, trust Leica Geosystems for all their geospatial needs. With precise and accurate instruments, sophisticated software, and trusted services, Leica Geosystems delivers value every day to those shaping the future of our world. Hexagon is a global leader in digital solutions that create Autonomous Connected Ecosystems (ACE). Hexagon (Nasdaq Stockholm: HEXA B) has approximately 20,000 employees in 50 countries and net sales of approximately 3.8bn EUR. Learn more at hexagon.com and follow us @HexagonAB.

Delair Introduces Open Payload Version Of Long-Range UAV

Custom Configuration Of Sensing Capabilities Enabled

Delair, a leading supplier of commercial drone solutions, introduced a new model of its popular long-range UAV, the Delair DT26, which offers an easy-to-integrate architecture for adding user-specified sensors and other payloads to the platform. The Delair DT26 Open Payload model features a removable container which can hold up to 3 Kg of extra payload and be connected to a power supply of up to 140W. It allows drone users to quickly add specialized sensors for specific imagery needs, such as ultra-high resolution, multispectral and hyperspectral, thermal and oblique imaging capabilities. An optional cargo rack can be used to transport any type of items up-to 3 Kg over the long distance range the UAV supports.

Aerial data collection in industries such as agriculture, oil and gas, utilities, construction and transportation infrastructure benefit from being able to configure specific solutions with the modular platform that the DT26 provides. In addition to enabling application-specific sensing configurations, the Open Payload model is also well suited for a range of other use models, including research and development projects, sensor testing and proof-of-concept projects.

Typical use cases could include adding: multispectral sensors for monitoring crop health or for asset maintenance; optical gas sensors to inspect equipment and pipelines and monitor for leaks; high resolution sensors for detailed orthophotos of infrastructure in transportation and energy; oblique sensors to get a different view of the same target from the same position; and thermal sensors for detecting hot spots, small detects in equipment and measuring performance of solar collection systems.

"The Delair DT26 is a production proven, long-range and high-performance UAV that now can be custom-configured for any number of use needs through its highly stable payload cabin. The rugged design provides a safe and secure platform for precise and thorough inspections that often require specialized components. The platform can also serve as aerial testbed for sensor research and training as well. The Open Payload version has been specifically designed for efficient integration of sensors that will work seamlessly with the overall flight operation and workflows the DT26 offers and at a very affordable price," said Benjamin Michel, Chief Product Officer at Delair.

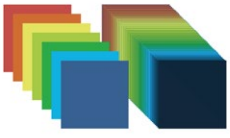
The Delair DT26 Open Payload model is supported by a technical diagnosis service that helps customers evaluate the compatibility of their specific payloads with the UAV's architecture.

Long endurance and high performance

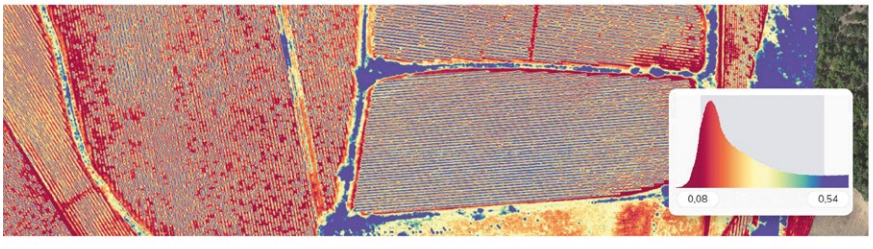
The Delair DT26 features a long endurance flying range of up to 135 minutes, enabling it to operate in BVLOS (Beyond Visual Line Of Sight). The integrated communication system supports both command and control as well as video datalink connectivity via radio or 3G cellular, and a maximum range of 30 km. It comes with very flexible mission planning and control software to ensure maximum productivity and ease of use.

The Delair DT26 Open Payload model is easy to deploy and transport, with typical deployment time of under 8 minutes. It can be launched in small spaces via its catapult take-off mechanism and features highly accurate belly landing capabilities, which enables it to land in challenging and remote terrains. Fully configured it weighs 17 Kg and features quick assembly components. A custom carrying case delivers more convenience for moving the UAV from project to project.

Delair is a leading provider of end-to-end, drone-based solutions that enable enterprises to digitize their physical assets and turn the collected data into valuable business insights. The company's offerings combine high performance, long range fixed-wing UAV hardware with Delair Aerial Intelligence (delair.ai), the industry's most powerful platform to manage, analyze and share aerial data. Its solutions are sold in over 70 countries with a network of more than 100 resellers in industries such as mining, construction, agriculture, oil and gas, utilities and transportation. Delair has strengthened its position as a global leader through strategic acquisitions (Gatewing, Airware/Redbird), and a strategic investment by Intel Corporation. Founded in 2011 by experts in the aerospace industry, the company employs 180 people and has offices in Toulouse, Paris, Ghent, Belgium, Los Angeles, Beijing and Singapore. For more information, go to delair.aero.



Multispectral vs Hyperspectral image



Multispectral versus hyperspectral image

YellowScan Opens YellowScan Japan in Tokyo

A Japanese based company, closer to Japanese needs

YellowScan, designer, developper and producer of UAV LiDAR solutions for professional applications, continues to expand its presence in Japan with the opening of a new office located at Shibuya, Tokyo.

In addition to the corporate headquarter in Montferrier-sur-Lez near Montpellier (France), the subsidiary in the USA, the new office in Japan supports the company's growth strategy. General Manager, Shinji Inaba, founder of Mirukuru, is set to head YellowScan operations at the Japan branch. Inaba-san brings over 20 years of experience and tactical know how of the Japanese market. Shinji Inaba says: "I'm so happy to start YellowScan Japan. We have many Japanese customers who require more services by UAV Lidar: civil engineering, mapping, infrastructure and especially recovery of disaster, as we have a lot of disaster. In this case, we need a quick and flexible service. Now, I can provide an even better support for Japanese customers and extend business with YellowScan Japan."

YellowScan Principal and Head of Sales & Marketing, Pierre d'Hauteville is very excited about this expansion to better support the Japanese customers: "Shinji Inaba leading the expansion of our company in Japan is a great asset. His experience within the photogrammetry and LiDAR mapping markets will ensure that our customers will continue to receive the best pieces of advice and support as they build their UAV LiDAR capabilities."

Tristan Allouis, YellowScan's CTO, adds "We have been partnering very successfully with Mirukuru's team for more than three years. The subsidiary will allow YellowScan to bring even more investments and technical expertise in the region."

The expansion will allow YellowScan to continuously serve its growing list of customers within Japan with exceptional local and tailored services for this market.

Shinji Inaba will continue to lead Mirukuru's operations. Mirukuru is providing world-class aerial technical products and services.

Don't miss the opportunity to meet the team during INTERGEO Stuttgart, GERMANY– September 17th to 19th (Booth A3.036).

At YellowScan we design, develop and produce UAV Mapping solutions for professional applications. Fully integrated, ultra-light and easy to use, these highly automated data collection tools are used by customers around the world in fields such as surveying, forestry, environmental research, archeology, corridor mapping, civil engineering and mining. With more than 14 years of field experience, YellowScan is committed to delivering the highest level of performance, reliability and robustness for its solutions. Our platforms are field tested all over the world in multiple environments (tropical forest, bare soil, mountains, rivers, coast lines, open-pit mine, power lines).

Mirukuru is a technical consultant, reseller and support provi`der for photogrammetry and LiDAR Mapping solutions. With 20 years of experience, the Mirukuru team is committed to provide the highest product quality and support to its customers.

Graham, *continued from page 48*

methods such as GNSS survey). This is bad for the industry in a multitude of ways.

Those a bit long in the tooth (such as myself) will recall that airborne lidar did not become the specifically cited collection method for digital flood insurance rating maps because it was better than the then ubiquitous stereo photogrammetry. No, requests for proposals began specifically citing lidar because of the intense lobbying (excuse me, educational) efforts of a few innovative thinkers who were spearheading this new technology. Within a very short period of time, RFPs were calling for *lidar* elevation models.

An even better example of changing the thinking of an industry is the North American Electric Reliability Corporation (NERC) *Recommendation to Industry* notice of 7 October 2010 that specifically called out airborne lidar as the recommended technology for collecting the as-built condition of transmission lines. This and other NERC actions resulted in over 500,000 line-miles of transmission line survey contracts being bestowed upon our industry.

The bottom line here is that we must embark on crusades to educate the client base on the *need* for drone-based lidar solutions. Some of this is easy; just show photogrammetry of overhead wires (they aren't there!). Other cases such as topographic mapping are much more nuanced and require some comparisons of vertical accuracy, images of missing ground under vegetation and so forth.

The goal is to move the industry to the state where lidar is part of the request. Rather than a request for topographic mapping, the RFP states "… lidar topographic mapping" or some similar phrase that specifically cites drone lidar collection as the methodology. So put on your convincing hat and hit the road!

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.

"Of course it's better!"

As I write this, I am sitting in an apartment in Castelnau-le-Lez, France, preparing to give a talk at the YellowScan lidar user group meeting. They didn't tell me what to talk about so I thought I would pontificate on technology adoption. In the midst of this, Allen Cheves (publisher of this magazine) reminded me by long distance that my Random Points article is overdue. Being in a crunch, it is time for me to duplicate!

Seriously, I have been thinking about the adoption curve of drone lidar systems. To us practitioners, the need for lidar on a drone is obvious—it is better technology than drone-based photogrammetry under a wide range of circumstances (but not all!). Is this clear, however, to the ultimate recipients of the data produced by these systems? Not yet.

The thing we, as either technology suppliers or service providers, tend to forget is that the recipients of our derived products (say a topographic data set) are often removed from the technology that was used in the collection of the source data. The client wants volumetric numbers that are within 3% of correct. When you ask for the meaning of "correct", you just get a strange look.

Sometimes you can convince the client with pictures. Clearly the logs imaged with photogrammetry (**Figure 1**) are inferior to those imaged with lidar (**Figure 2**). But does the recipient of the feeder stock inventory at the paper mill care? Does she even see these models or is she simply reviewing cubic meters (feet) in an Excel spreadsheet?

The same applies to topographic mapping. The client requests a raster elevation model (more likely, I have found, a set of topographic contours at a specified interval), not a "lidar" ground model.

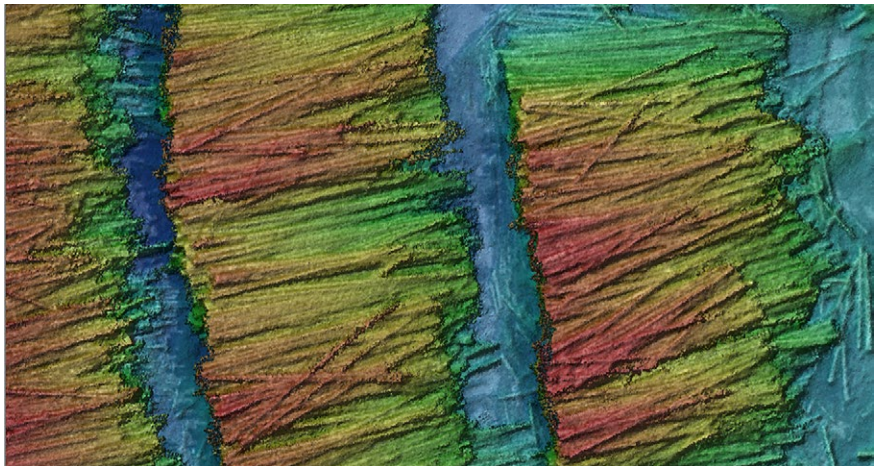


Figure 1: Log piles modeled with photogrammetry.

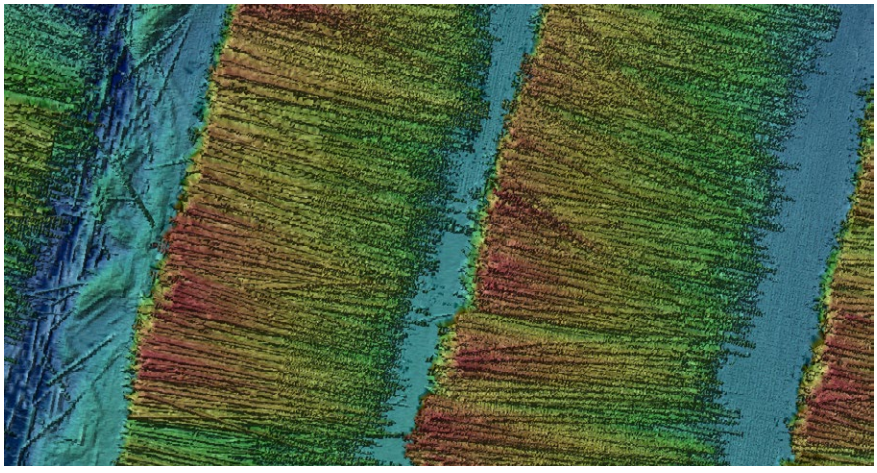


Figure 2: Log piles modeled with lidar.

We in the American Society for Photogrammetry and Remote Sensing (ASPRS) have long advocated *product* driven specifications. We would prefer to discuss a 1 meter elevation raster with Root Mean Square Error (RMSE) less than 10 cm rather than specifically require a photogrammetrically derived elevation model. Nevertheless, I am beginning to see that when a technology is new to the market, we really must discuss the merits of the collection system. When all you have is a hammer, everything you encounter is a nail. We see drone service providers who have only a camera system delivering products that could really only be generated with lidar (or ground-based

continued on page 47

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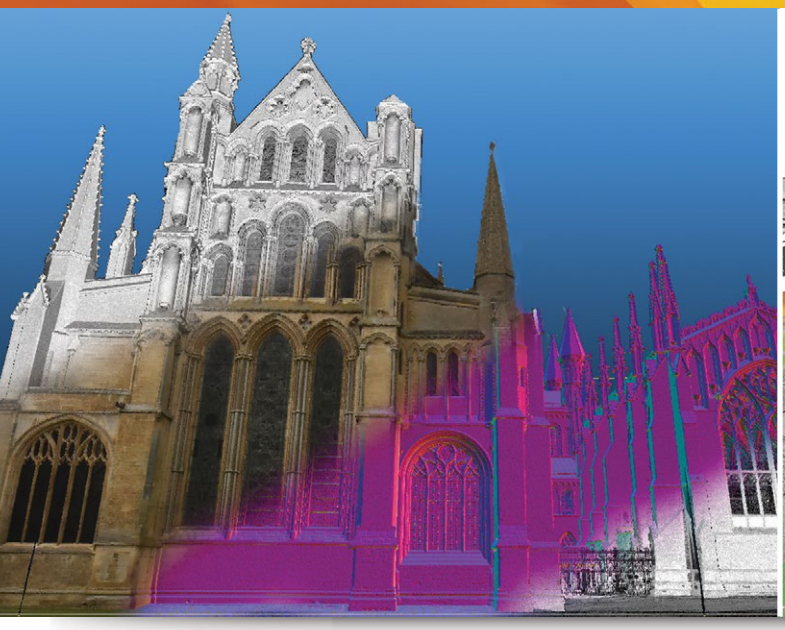

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