VOLUME 14 ISSUE 1

LIDAR MAGAZINE

WINTER 2024

SPECIAL ISSUE

ARCTIC FIELD WORK

Mosquitos and Improvisation

8 LIDAR LEADER AWARD PREVIEW
Meet this year's exceptional group of finalists for our individual achievement, team, and innovation awards

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Resilience and improvisation were in order for a team that set out to scan a remote portion of Canada's northern archipelago

24 TRANSFORMED TRAJECTORIES
Applanix strengthens integration and pushes processing boundaries on an underground parking project in China

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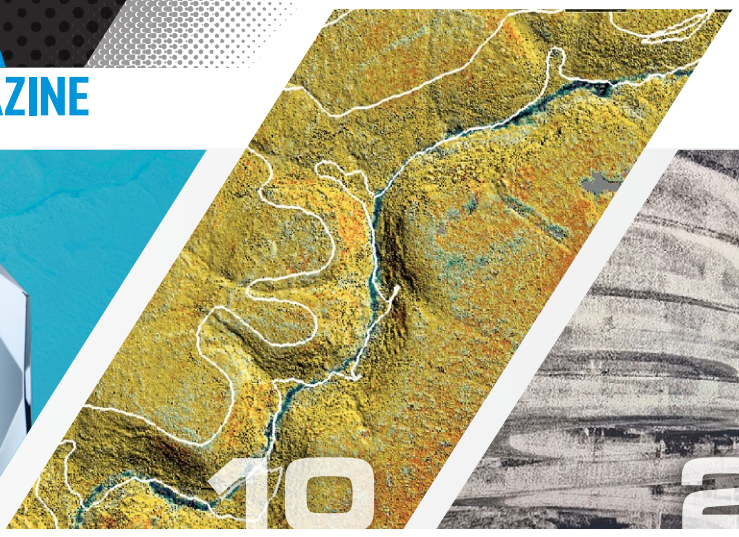

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In conjunction with Geo Week, we've once again opted to celebrate the accomplishments of leaders in our field at the Lidar Leader Awards, a joint initiative of LIDAR Magazine and the organizers of the International LiDAR Mapping Forum (ILMF). Within this year's preview, we've highlighted some of the finalists from each award category. Four categories were offered this year: Outstanding Personal Achievement in Lidar Outstanding Team Achievement in Lidar and Outstanding Innovation in Lidar. In Denver, we also address Outstanding University Achievement in Lidar. This category is open to all universities, students and teams within the university.
COMPILED BY EDITORIAL STAFF

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In the historical era of expeditions, simply reaching the unknown and dangerous destination was usually one of the biggest challenges. Scientific research was carried out, but exploration was perhaps the premier motivation. Today's day expeditions are usually very focused on science. Though transportation has become much easier, the challenge of delivering top scientific results in the high arctic requires the right people, training and attitude. This account of mosquitos, muskox encounters and an emergency solution for the camp freshwater highlights the fact that expeditions are still adventures that require resilience and improvisation.
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24 Transformed Trajectories
As an industry leader in mobile mapping solutions, Trimble Applanix is well known for its pioneering advances in the GNSS/inertial space for land, air and sea-based applications for a wide variety of industries. In the past year, the company has introduced several interesting and impressive advancements including a high-accuracy navigation package and a lidar-based georeferencing optimization solution. Both innovations were put to work on a project in China with impressive results. NavInfo, China's leading location service and smart mobility solution provider, was tasked with mapping a large underground parking lot with roughly 1,000 parking spaces.
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Image courtesy of the Finnish Geospatial Research Institute.

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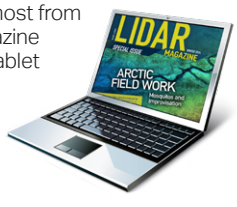

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DR. A. STEWART WALKER

Celebrating World Lidar Day

You may have picked up *LIDAR Magazine* at Geo Week, or you may be an existing subscriber. Or both. Thank you.

In the last issue we announced our series of podcasts. These are continuing and are proving both interesting and attractive to our readers. We are grateful to the guests and look forward to welcoming many more. Now I understand why relaxed, elegant, entertaining talk-show hosts on TV are so highly paid—it's stressful to provide an engaging conversation with an eminent guest and the preparation has to be meticulous!

The 2024 Geo Week is certainly the biggest, liveliest ever. Participants will be familiar with GIS Day, a familiar fixture on the geospatial calendar, celebrated around the globe with all sorts of events and initiatives. Well, we too felt that our own technology deserves recognition, so we joined a group of public agency and private industry representatives to raise awareness about the value of lidar. As a result of these efforts, the first instantiation of "World Lidar Day" is now slated for 12 February 2024, right in the middle of Geo Week, and it will be an annual event.

Already, numerous major organizations have signaled their support, with a complete list detailed at a recently unveiled eponymous website[1]. I've talked many times in these pages about how often laser scanning and related technologies are mentioned in the popular press[2]—so let's do our best to publicize, both inside and outside the geospatial community, its growing popularity and value.

Another annual favorite on the lidar calendar is the presentation of the Lidar Leader Awards, now in their fifth iteration. Though not a coincidence, this year's ceremony will also be held on 12 February. For 2024, there are three categories and four winners, each profiled on page 8 although I'll take a moment to address them here.

The Lidar Leader Award for Outstanding Innovation in Lidar goes to Blue Marble Geographics for its Custom Point Cloud Classification tool for training classifiers, part of Global Mapper Pro[3].

A most unusual situation unfolded with respect to the Lidar Leader Award for Outstanding Team Achievement in Lidar. The summation of the votes of the jurors resulted in such a close result that Diversified Communications generously offered to provide two trophies, going to

1 lidarday.com

2 For example: theguardian.com/us-news/2023/feb/23/lidar-technology-archeology-radical-thinking; theguardian.com/environment/2023/may/12/scotland-annual-laser-scan-monitor-forest-health-aoe; theguardian.com/science/2024/jan/11/amazon-archaeology-lost-cities-ecuador; economist.com/science-and-technology/2023/11/08/israel-hopes-technology-will-help-it-fight-in-hamass-tunnels

3 bluemarblegeo.com/how-to-train-a-custom-point-cloud-classification-in-global-mapper-pro/

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very different organizations: Singapore Housing & Development Board and the U.S. Army Corps of Engineers. These teams' projects were, respectively, Intelligent Mapping and Querying of Singapore's Residential Estates[4] and the National Coastal Mapping Program[5].

The winner of the Lidar Leading Award for Outstanding Personal Achievement in Lidar is Arttu Soininen at Terrasolid[6]. Arttu is very well known, having started the company more than 30 years ago. He has traveled the world endlessly, covering all the bases when the firm was small to more specialized efforts at conferences and customer sites as it has grown. Indeed, I remember visiting him in Helsinki, on a dreich day at the end of autumn 1995, to learn about Terrasolid, at that time more for processing photogrammetric data than lidar. In due course, customers with the Leica ALSxx airborne lidar scanners depended on Terrasolid products to generate their deliverables. Nowadays, there's a wide choice of software for these tasks, but Terrasolid set the pace. The structuring of Terrasolid software atop Bentley Systems' MicroStation, moreover, changed how we viewed and used technology in those early days.

This edition of the magazine contains numerous corporate listings which ultimately finance our publishing. A sincere thanks is in order to each of the firms represented as their continued sponsorship allow us to do what we do. We should perceive them in a different way, however, not just as part of each firm's marketing efforts, but, collectively, as a microcosm of our industry today, growing, vibrant and technologically leading-edge. We are well aware that end-users demand more frequent, more accurate, more dense, more comprehensive yet more economical data plus the increasingly insightful deliverables derived from it—the listings show that this is indeed happening. And it's not just the ever more capable and cost-effective sensors and software—it's the army of talented, committed professionals who develop, distribute, support and, above all, deploy these products to meet end-users' needs. Temper that with a rich mix of business development and project management skills and the result is an industry of which we are all proud, but which won't stand still as it meets new challenges and solves fresh problems.

The cornucopia of listings leaves space for only two feature articles. It's a while since we published an article from Trimble Applanix, an unfortunate omission since the firm's GNSS/IMU solutions are at the heart of so many lidar systems on crewed aircraft, UAVs and land vehicles. The piece by Vicki Speed describes some of the latest Trimble Applanix developments and their use in several very disparate applications.

In the last issue we welcomed a new and accomplished contributor, Antero Kukko, a professor from the Finnish Geospatial Research Institute who is an acknowledged lidar expert[7]. We are pleased to include a second piece from him, about laser scanning on remote Axel Heiberg Island in Canada's arctic archipelago. The logistics of moving people and equipment to the research site are as intriguing as the lidar itself, to say nothing of the appearance of a muskox to observe the laser scanning process. The data collected was invaluable for geomorphological and hydrological studies of this lonely place.

Not long ago we added a new Contributing Writer, Amar Nayegandhi, senior vice president at Dewberry and another very familiar name in the lidar world[8]. Although he has been co-author of multiple articles in the magazine, we are pleased to publish in this issue his first piece as a Contributing Writer. Amar hopes that these articles will straddle technology and business, exploring how the latest technologies are actually being used and how they influence the thinking of leaders in geospatial businesses and organizations. His first analysis looks at the complementariness of lidar and sonar, but the use of these technologies in tandem implies a coalescence of two communities, topographic and hydrographic, with different cultures and approaches. There's more to it than Dewberry's dramatic nomenclature, "Fly lidar first, fill-in with sonar"! Amar's contribution supplements, to some extent, our recent article on the Florida Seafloor Mapping Initiative[9].

We hope that the content in these pages piques your interest and makes you look forward to *LIDAR Magazine* appearing in your mailbox and/or screen. Thank you once again for your support. Think about our technology and profession on World Lidar Day and have a wonderful 2024.

A. Stewart Walker // Managing Editor

4 hdb.gov.sg/cs/infoweb/homepage
5 sam.usace.army.mil/Missions/Spatial-Data-Branch/JALBTCX/
6 terrasolid.com
7 Kukko, A., 2023. Multispectral lidar for environmental applications, *LIDAR Magazine*, 13(4): 30-34, November/December 2023.
8 lidarmag.com/2022/04/30/new-author-introduction-amar-nayegandhi-cp-cms-gisp/
9 Karlin, A., E.S. Klipp and A. Nayegandhi, 2023. Mapping Florida waters, *LIDAR Magazine*, 13(4): 24-28, November-December 2023.

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LIDAR LEADER AWARDS

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In conjunction with GeoWeek, we've opted to celebrate the accomplishments of leaders in our field at the Lidar Leader Awards, a joint initiative of LIDAR Magazine and the organizers of the International LiDAR Mapping Forum (ILMF). Over the pages that follow, we've highlighted some of the finalists from each award category. As you'll find, the nominations embody a galaxy of lidar talent. All winners will be provided the opportunity to highlight their perspectives in an upcoming edition of the magazine.

Four categories were offered this year:

Outstanding Personal Achievement in Lidar

Outstanding Team Achievement in Lidar *(2-99 members)*

Outstanding Innovation in Lidar

This category was created to honor recent projects or products that appear to be ground-breaking.

Outstanding University Achievement in Lidar

This category is open to all universities, students and teams within the university, who must demonstrate an exceptional achievement within the realm of lidar technology.

Editor's note: The text that follows has been excerpted from original nominations and in no way defines the views or opinions of the award committee, the organizers of ILMF or LIDAR Magazine. Some text has been edited for clarity and length.

Congratulations to the following winners...

Outstanding Personal Achievement in Lidar

Arttu Soininen, Terrasolid

The award for **Outstanding Personal Achievement in Lidar** is awarded to individuals who have made a significant impact to their organization and community, either through technical excellence, professional development, or innovation within the realm of geospatial lidar technology. This year, the award is presented to **Arttu Soininen** at **Terrasolid.**

Soininen is known as the visionary head software developer at Terrasolid and epitomizes excellence in the geospatial industry. His contributions have streamlined workflows, saving time and resources across multiple sectors, from urban planning to cultural heritage preservation. With an impressive 30-year journey in survey data processing and over 22 years innovating lidar processing techniques, Soininen is the mastermind behind the world-renowned TerraScan, TerraMatch, TerraPhoto, and more.

Outstanding Innovation in Lidar

The **Outstanding Innovation in Lidar** award is given to products, business models or technology on the market for less than one year, and this year is being awarded to the **Global Mapper's Custom Point Cloud Training Tool** from Blue Marble Geographics

BLUE MARBLE GEOGRAPHICS

Blue Marble Geographics was nominated for its outstanding innovation in creating a groundbreaking new functionality for training custom automatic point cloud classifications. The Custom Point Cloud Classification Training Tool results from years of work in lidar and point cloud processing within Global Mapper Pro. Blue Marble Geographics has been innovating methods for classifying and editing point clouds for almost a decade, making strides in generating photogrammetric point clouds and processing them along with aerial and terrestrial lidar while keeping these tools financially accessible.

Outstanding Team Achievement in Lidar

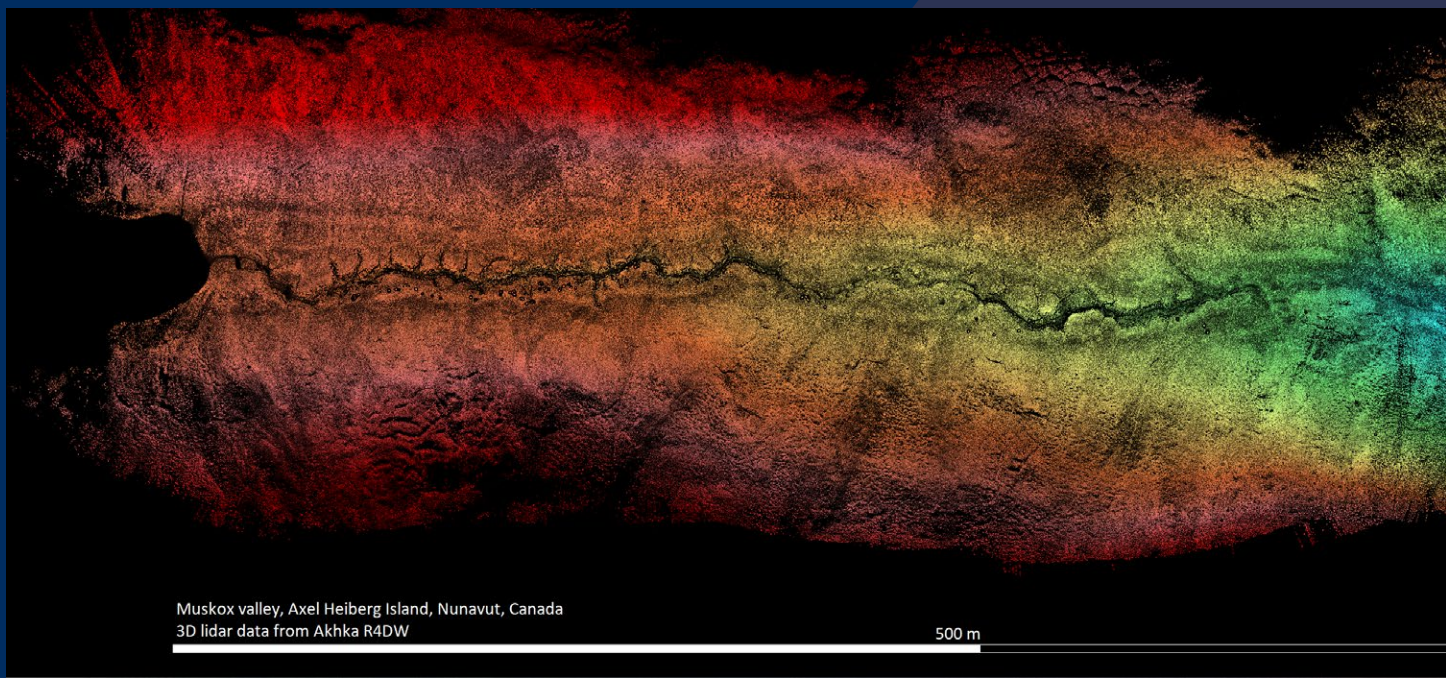
Outstanding Team Achievement in Lidar awards are given to teams who have demonstrated a unique achievement in service, project management, or product development. This year, the winners of this award are the **Singapore Housing & Development Board** for their work in **Intelligent Mapping and Querying of Singapore's Residential Estates** and the **U.S. Army Corps of Engineers** for their **National Coastal Mapping Program.**

HOUSING & DEVELOPMENT BOARD

Housing & Development Board (HDB), which is the public housing authority in Singapore, has pioneered 3D Light Detection and Ranging (lidar) scanning within residential estates to support its effort to provide world-class public housing for the nation. In its digitalization journey towards producing sustainable yet feature-rich geospatial datasets, HDB has utilized point cloud data to its tremendous potential in supporting operational workflows, providing services, and enabling advanced analytics.

NCMP

The U.S. Army Corps of Engineers (USACE) National Coastal Mapping Program (NCMP) was established to support regional sediment management through the national dredging program. NCMP is the culmination of a decades-long program that developed and evolved the first U.S. lidar bathymeter into the first topo-bathy lidar for coastal mapping and charting. NCMP is the only federal program that maps the U.S. coast on a recurring schedule, providing high-resolution elevation and imagery data to measure and monitor the U.S. coastline accurately. This data and the products they inform are vital to navigation safety, floodplain management, coastal resilience, economic development, emergency response, ecosystem restoration, and sediment management.



Finns Use Lidar in Canada's Northern Archipelago

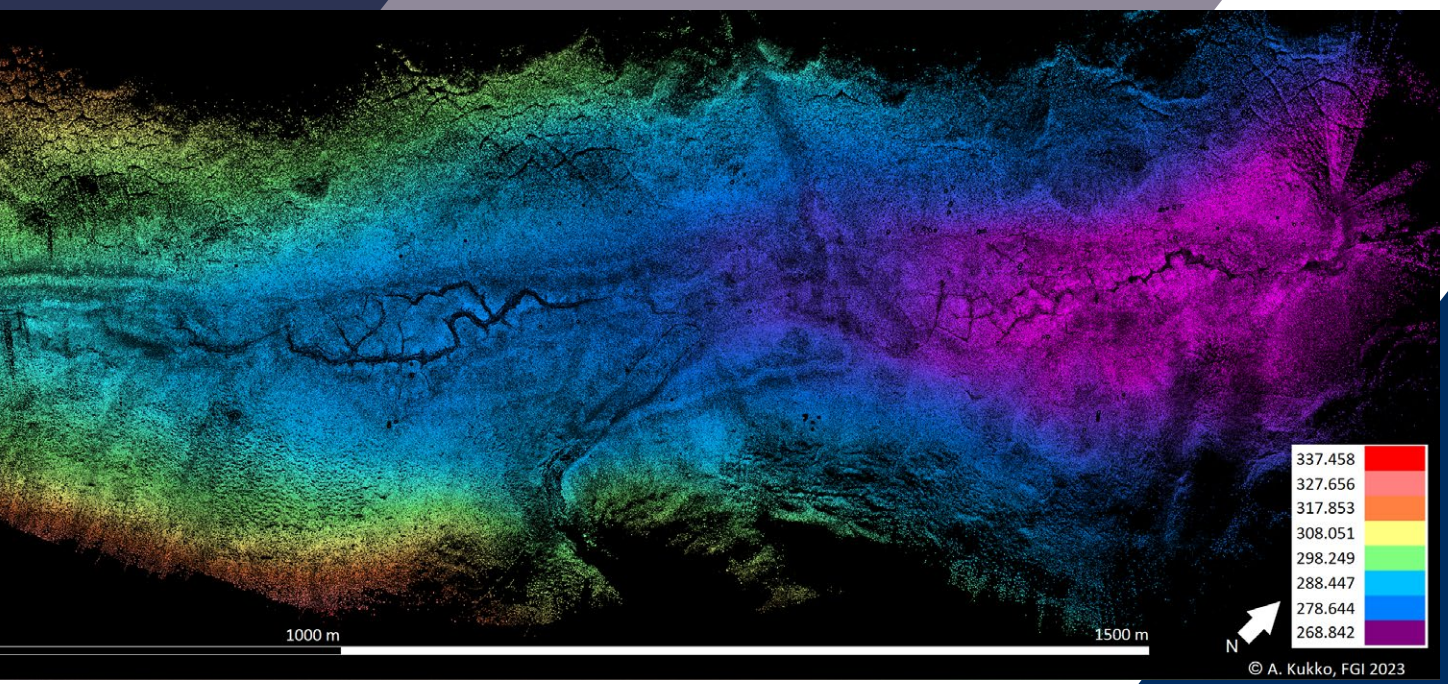
Mosquitoes and improvization—arctic field work to scan Muskox Valley

In the historical era of expeditions, simply reaching the unknown and dangerous destination was usually one of the biggest challenges. Scientific research was carried out, but exploration was perhaps the premier motivation. Today's expeditions are usually very focused on science. Though transportation has become much easier, the challenge of delivering top scientific results in the high arctic requires the right people, training and attitude. This account of mosquitos, muskox encounters and an emergency solution for the camp freshwater highlights the fact that expeditions are still adventures that require resilience and improvisation.

BY ANTERO KUKKO

Journey begins

In 2019 I was offered an opportunity to join a Canadian-US team for field work in the archipelago of the Canadian high arctic. I had been in that Inuit territory in 2016 and 2017 on Devon Island, the largest uninhabited island on Earth, studying land formations in and around the Haughton impact structure and close to the ice cap in the east of the island. This time I was able to venture



Elevation model of Muskox Valley based on the expedition's lidar data. The glacial lake is located to the left of the image, and the glacier front is further to the south-west, beyond the left of the image. The valley continues to the north-east to join a river further down. The muskox encounter took place at the edge of the image to the right.

Glaciated landscape of southern Axel Heiberg island.

further north, to Axel Heiberg island in Qikiqtani region, Nunavut.

In 2014 I had been contacted by a laser-scanner distributor with a request to rent an instrument for a US-based planetary researcher. We made an agreement to lend them one of our terrestrial laser scanners, on condition that we could join the team for a field study in Saaremaa, Estonia to scan the

Twin Otter (Ken Borek Air Ltd.) being loaded at Resolute Bay airfield to airlift us to the expedition.

Camp in sight! The first half of the team got the camp going prior to our arrival. Large polygon formations prominent to permafrost terrain are seen across the river plain. White traces reminiscent of snow on the ground are salt.

Unloading cargo from the plane. These small ATVs provide a handy means of travel—usually we could do day trips 25-30 km away from the camp. Climbing twice to the 450 m high plateaus seen in the background to reach study sites with all the laser equipment, water and food for a day, carrying out several hours of scanning and hiking back to the camp was memorable!

Kaali meteorite impact structure with a backpack scanner we had developed just a year earlier. This collaboration with Mike Zanetti (now NASA) brought me in contact with the planetary research team from the Institute for Earth and Space Exploration, University of Western Ontario, Canada, and later with scientists from University of British Columbia, Arizona State University and Simon Fraser University.

At the end of June 2019, after months of planning and numerous remote meetings, I flew from Helsinki to Ottawa, where I met the rest of the team. The flight route from there took us to Iqaluit, then on a turboprop via settlements in Clyde River, Pond Inlet, Arctic Bay all the way to Resolute on Cornwallis Island, where the Polar Continental Shelf Program (PCSP) of Natural Resources Canada runs a base to support logistics for research and other activities.

PCSP base provides research teams with accommodation, catering services and logistical support to reach remote camps and study sites all across the vast span of Arctic desert islands. In the storage hall, each team doing long-term research in the region has its own cage room to store camping and field gear and desiccated food supplies. Fresh food was freighted for the season and collected from the PCSP storage along with ATVs for transportation, gasoline and generators for electricity, and natural gas stoves. Bear bangers, whistles, guns and briefings to be ready for possible encounters with polar bears were also necessary, completed with training with live rounds at the camp on the first evening on Axel Heiberg island.

Arrival at Axel Heiberg island

It took two flights of the Twin Otter to move the team and equipment to Axel Heiberg island. The 550 km flight crossed glaciated mountains, retracting ice lobes in valleys, and arctic desert landscape.

The plane circled around the sunlit camp set on a meltwater river plain and landed to the west. We stopped next to the space dome, our living room for the next couple of weeks. We unloaded the gear, the plane accelerated across the makeshift airfield, took off and we were alone in the middle of nowhere.

After improvizing with a bucket and cloth after the camp's water filter had become clogged by river mud, we settled into daily life. The morning routine included scheduled radio communication checks with PCSP. Satellite phones were available and useful when the team was split between various, often very

The Muskox Valley was a spectacular, serene sight despite the millions of mosquitoes. The low U-shape of the valley is very clear. There were green pastures at the bottom of the valley - the living room of the muskox. Lidar mapping was carried out meticulously following the troughs and other terrain features to capture the valley topography.

Sites beyond a hike, climb or ATV ride were reached with a helicopter operated by Universal Helicopters (this business no longer exists). We had four helicopter days during the campaign, so the site visits were carefully selected and prioritized. On the ground at the front lies the Akhka-R4 lidar backpack that was used for mobile laser scanning of the permafrost and periglacial landforms on various sites on Axel Heiberg island. To the right is the GNSS base station used for correcting the lidar positioning data, the camp generator and radio mast are visible too.

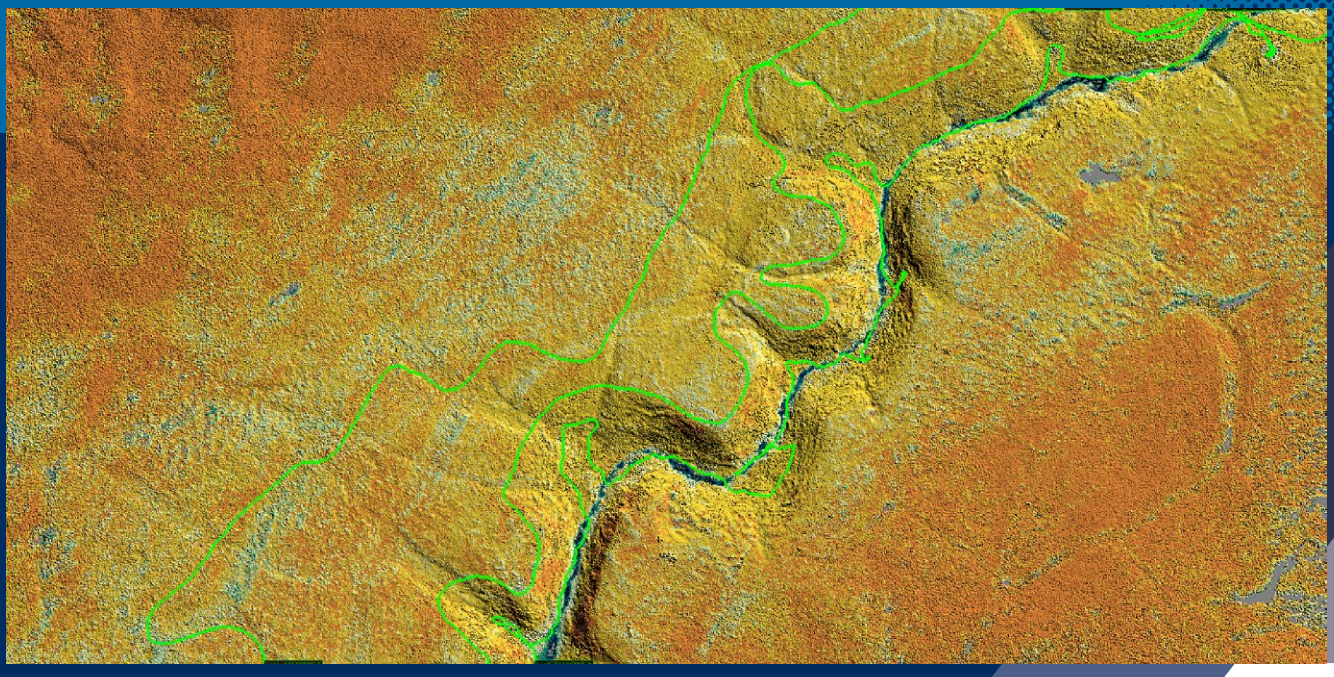
distant field sites to check status, and inform travel routes and rendezvous, coordination that was especially critical on days when we had helicopter transport. Electricity was provided by a small 2 kW generator to charge the batteries of computers, GNSS devices and science equipment.

After a day in the field there was backing up, data processing and and completing field notes. The sun was up all night long, so the long days gave ample opportunity for work tempered by sleeplessness.

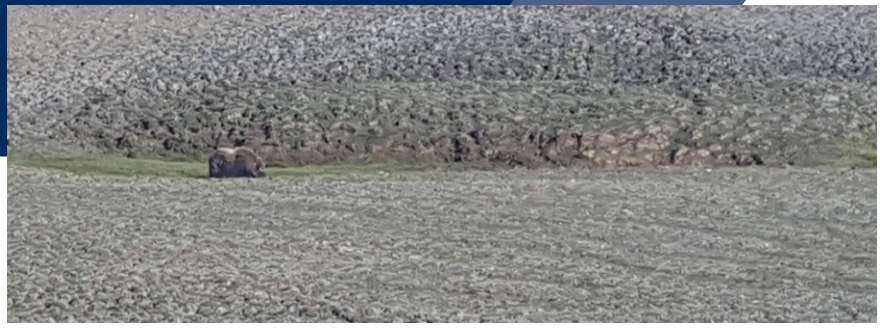
Trip to Muskox Valley

On the expedition's sixth day, three team members made a trip to a then unnamed glacial valley, expected from satellite imagery to be interesting for studying subglacial channel morphology and hydrology. The plan was for the helicopter to drop us off for other duties. The site was located about 60 km north of the camp, so the short flight saved considerable effort crossing multiple rivers and rugged terrain on ATVs.

We circled briefly around above the valley for photography and reconnaissance of the site before landing on a selected spot which was to become the lower end of the scanning work with the backpack



Snaking the terrain to capture the details. The backpack's mobile lidar trajectory is shown in green on top of the reflectance-colored terrain data.



The owner of Muskox Valley grazing in its natural habitat. The slopes of the valley provide very little fresh fodder in mid-July.

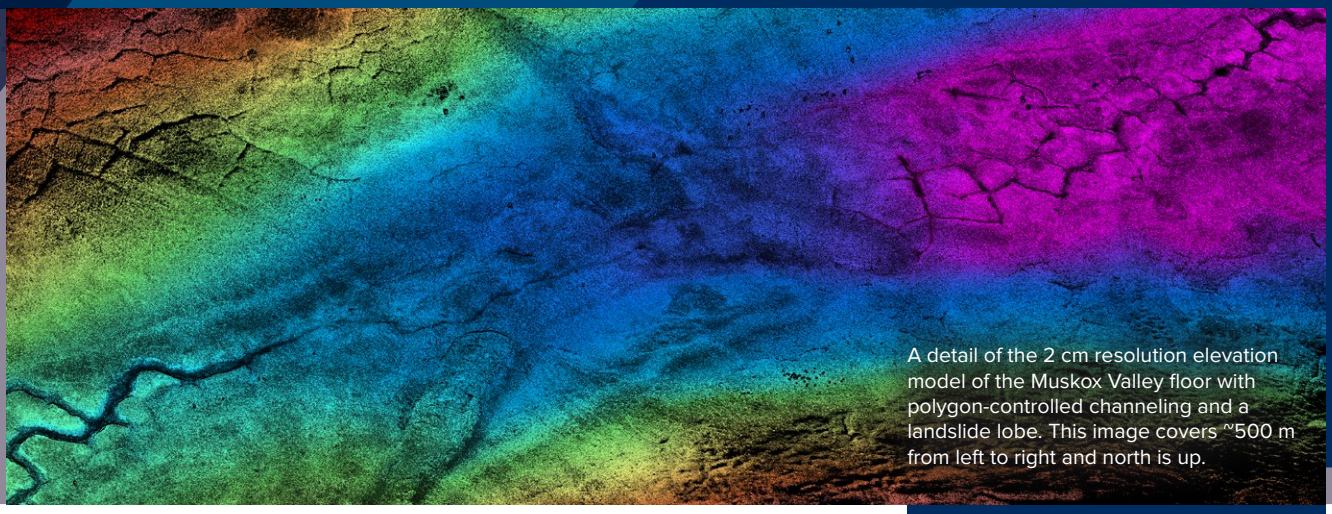
lidar. The topmost point would eventually be about 2 km distance up the valley by a small glacial lake. The site occurs within a recently deglaciated valley on the eastern side of the island and lies a few kilometers to the southeast of a prominent ice lobe extending from the Müller Ice Cap (79° 54 '44.4"N, 89° 10' 37.1"W). The full valley is 8 km long and 1 km wide, and has a flattened U-shape, typical for a formation of subglacial origin. The eastern Axel Heiberg region has a polar desert climate with an annual mean air temperature of -19°C. During our expedition, however, we experienced 15-20°C day temperatures, compared to the July average of 6°C for the past 40 years.

We could feel the fresh breeze with a smell of the glacier a few kilometers to the west. The valley was covered with tundra vegetation, small white flowers blooming all over, low grass looking burnt dry higher on the valley slopes, but lush at the bottom and in the polygon troughs where traces of streaming water and small bonds could be found.

We waved the helicopter off, and set up for the scanning and site survey. A team member volunteered for the first try-out of the backpack scanning, so I gave him an introduction on how to paint the scene with my lidar brush, and soon he started snaking up the valley from side to side and contouring the trough formations to capture the terrain topography of the valley. Another member started photographing and making a survey of the valley sediments, hydrology and landforms. I was bear watchperson and explored the terrain—especially intriguing was a landslide lobe protruding into the valley from the southern slope.

We switched tasks when we changed batteries and we were privileged to see a muskox standing near a small crest on the southern slope where the valley narrowed. The animal was curious, but not delighted that humans had invaded its home, so we kept our distance and no incident occurred. We decided to give the beast space, headed from its location up to the shore of a small oblong glacial lake and set the instrument down for

Concretions. Meltwater erodes sharp channels through the landscape. I came to this location down from the glacier along the channel to the right.



A detail of the 2 cm resolution elevation model of the Muskox Valley floor with polygon-controlled channeling and a landslide lobe. This image covers ~500 m from left to right and north is up.

a break. We started to scan the very prominent troughs at this location, following the channel back down the valley. We pondered the marks of a lake outburst and relatively recent lowering of the lake surface. We completed the scanning of the middle portion and the upper slopes of the area in the valley.

As a result of the scanning we could reconstruct the topography of the site, now dubbed as Muskox Valley. Back home the lidar data was processed into a very high-resolution digital terrain model with 2 cm resolution. This permitted computational analysis of the properties that characterized the valley morphology, channelization and hydrodynamics, and for assessing erosion and sediment transport in the event of a glacial lake outburst. Based on this model and field study we could perform scientific analysis and simulations. The findings have been published[1].

The current expression of surface channels along Muskox Valley is diverse, depending on the presence or absence of polygons. The high-resolution lidar model shows that the character and extent of erosional channel incision is spatially discontinuous along the valley. Whereas well-developed channels are common around the edges of large polygons and

1 Chartrand, S.M., A.M. Jellenek, A. Kukko, A.G. Galofre, G.R. Osinski and S. Hibbard, 2023. High arctic channel incision modulated by climate change and the emergence of polygonal ground, *Nature Communications*, 14, 5297. https://doi.org/10.1038/s41467-023-40795-9.

Nomenclature

Polygon ground: the distinct and often symmetrical natural pattern of geometric shapes formed by the deformation of ground material in periglacial regions. Polygons can form either in permafrost areas (as ice wedges) or in areas that are affected by seasonal frost.

Brain terrain: a feature of the Martian surface, consisting of complex ridges found on lobate debris aprons, lineated valley fill and concentric crater fill. It is so named because it suggests the ridges on the surface of the human brain.

Concretion: a hard, compact mass formed by the precipitation of mineral cement within the spaces between particles, and is found in sedimentary rock or soil. Concretions are often spherical in shape [source: Wikipedia].

Eureka International Airfield offers all the basics a frequent flyer needs.

within inter-connected troughs, channelization is diffuse or non-existent where relatively poorly developed polygons occur in wetlands. Polygon geometry seems to be able to influence, even govern the channel path both across and down topographic gradients at the valley.

Wrapping up the expedition

During the two weeks I performed scans towards the expedition goals at multiple locations near the camp, up on the plateaus west of camp and even at a couple of locations in the vicinity of Strand Fjord on the west side of the island. Some of the scans were quite extensive, such as subglacial valleys and a thaw slump that took multiple hours of mapping, and some more localized patterned ground features. For one study we scanned a large section of polygon formation on the southern slope of the Strand Fjord at its east end. The most peculiar place was the so-called brain terrain formation about 30 km north-east of camp. Brain terrain is an extraterrestrial feature seen extensively on the surface of Mars, but the location seems to have an analog here on Earth. Two team members also carried out ground-penetrating radar surveys to reveal ice wedges and other structures beneath. One day I scanned a narrow glacial meltwater channel eroded through the permafrost ground and ice. The channel opened up to a larger stream and rapidly rushing waters, where erosion had exposed many concretions of various sizes, the largest of which I saw was about 1 m in diameter.

Time for farewell in good spirits.

The author on a hike to a plateau on Axel Heiberg island in July 2019. His Akhka-R4 backpack lidar system provides an efficient survey tool to map terrain topography at high resolution.

Like the trip to the site, the return required two flights. After the departure of the first plane out, a smaller group was yet able to do more fieldwork and data backups, finalizing fieldnotes, data processing and other tasks.

On our way out (from Axel Heiberg) we flew via Eureka International Airfield, which is the northernmost settlement I have visited thus far on my journeys. We stopped there to refuel the airplane and had a brief vision on the station. And thus ended a memorable lidar expedition.

Antero Kukko, DSc is a research professor at the Finnish Geospatial Research Institute (part of the National Land Survey of Finland) and leads the Autonomous Mapping and Driving research group of 40 personnel. His research interests include integrated mobile, UAV and airborne laser scanning systems, positioning, autonomous systems, and applications and computational methods using multi- and hyperspectral lidar for geospatial research, mapping, forestry and geomorphology.

SPONSORED LISTING INDEX

The following pages provide an overview of key service provider, sensor hardware, software and component part manufacturers, in addition to system integrators. Visit the online directory at *www.lidarmag.com* for additional listings.

We encourage you to visit our sponsors.
Thanks to all that participated in this year's edition.

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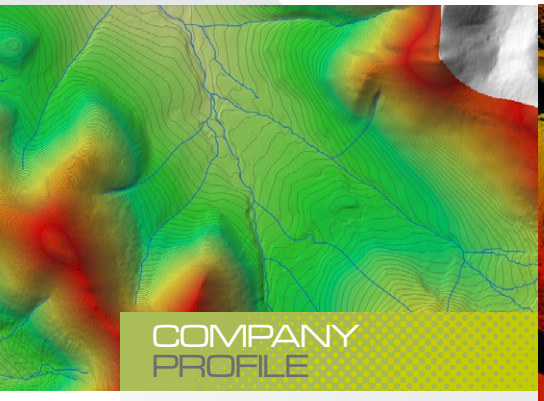
Surdex Corporation



COMPANY PROFILE

Surdex Corporation is a geospatial mapping firm based in St. Louis, Missouri that has been supplying best-in-class geospatial information to clients for 70 years. Our clientele includes a wide range of government entities and businesses. We offer several services, including aerial image acquisition, lidar acquisition and processing, digital orthoimagery production, and planimetric and topographic mapping.

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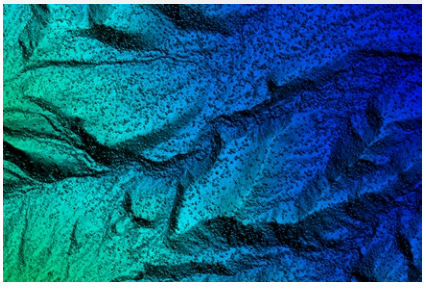
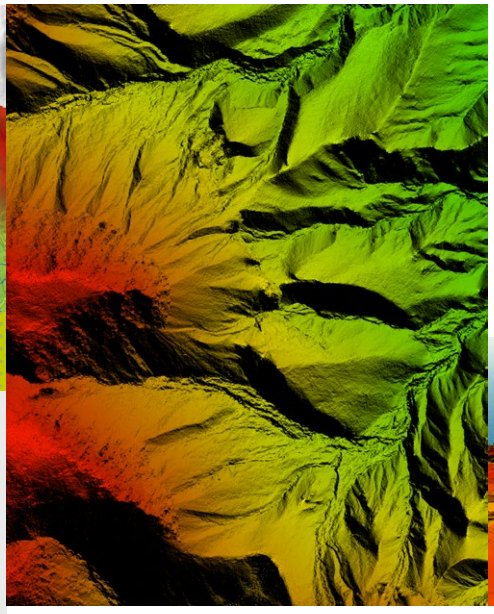
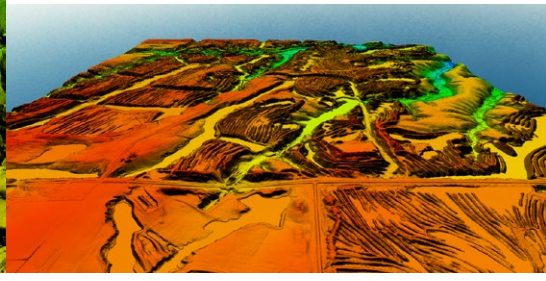




APPLICATIONS

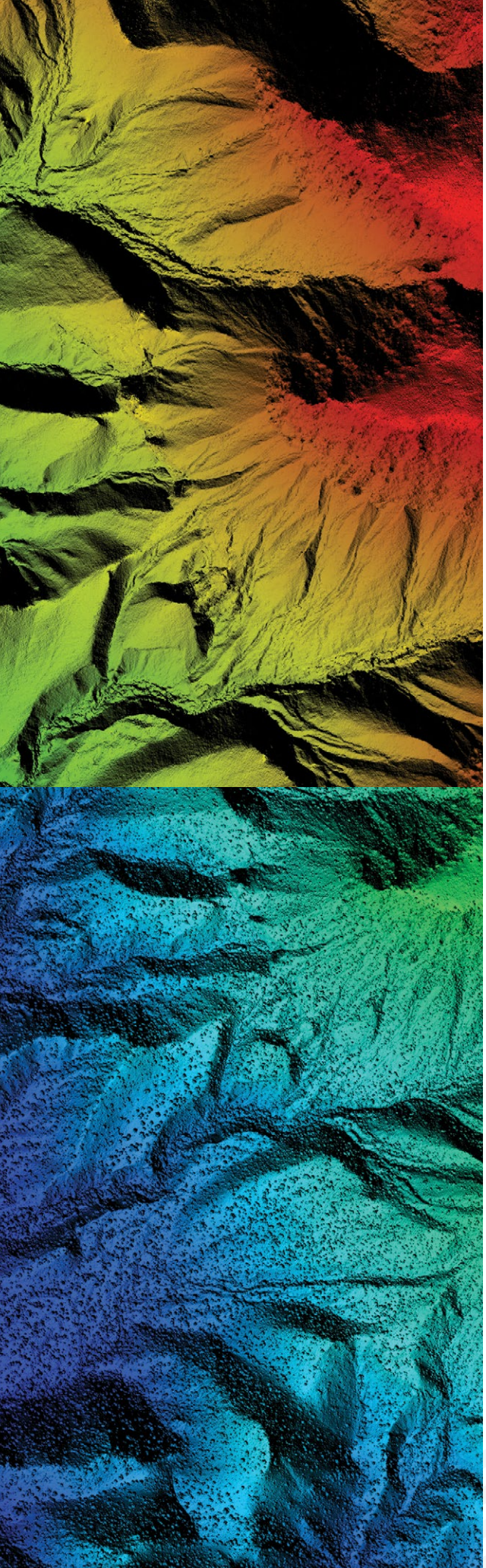
- AERIAL LIDAR ACQUISITION
- LIDAR PROCESSING
- AERIAL DIGITAL IMAGERY ACQUISITION
- DIGITAL ORTHOIMAGERY PROCESSING
- TOPOGRAPHIC MAPPING
- PLANIMETRIC MAPPING



Surdex: Your Strategic Geospatial Resource

Surdex Corporation is a photogrammetric mapping firm based in St. Louis, Missouri that has been supplying a full spectrum of accurate and precise geospatial information to clients for 70 years. Our wide clientele base includes federal, state and local governments, as well as private entities such as engineering firms and energy sector businesses. We provide our clients with high-quality mapping services including aerial image acquisition, lidar acquisition and processing, digital orthoimagery production, and planimetric and topographic mapping.

Surdex owns a fleet of 10 aircraft, 10 digital aerial cameras and 3 airborne lidar sensors. Aircraft maintenance, inspections, and repairs are performed in-house, enabling us to optimize operational time. We process our data using customized software coupled with open source and third-party software. Surdex has several active multi-year contracts including an Indefinite Delivery / Indefinite Quantity (IDIQ) contract with the US Army Corps of Engineers (USACE), a US Geological Survey (USGS) Geospatial Products and Services (GPSC4) agreement, and a federal General Services Administration (GSA) contract, which includes the National Agriculture Imagery Program (NAIP). We also complete dozens of county and municipal government projects annually and have several state DOT contracts.



Your Strategic Geospatial Resource

- Classified lidar point cloud
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NV5

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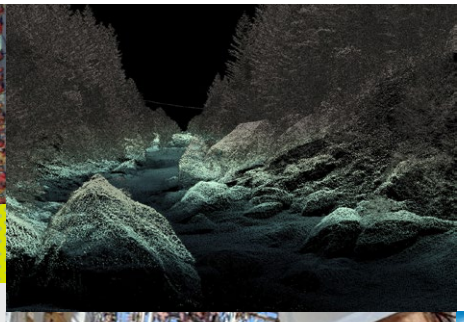
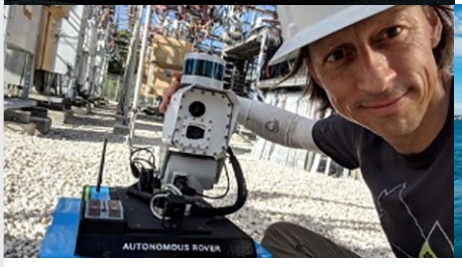


APPLICATIONS

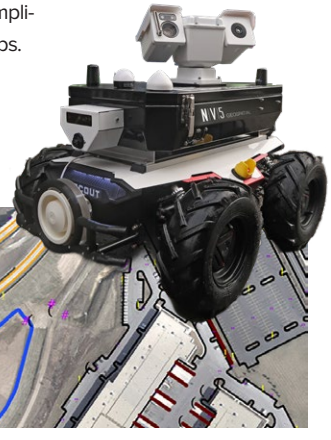
- SURVEYING AND MAPPING
- DIGITAL TWIN
- DATA & IMAGE PROCESSING
- ANALYTICS
- SOFTWARE & BUSINESS SOLUTIONS
- ENTERPRISE GIS & CLOUD
- FACILITY & SYSTEM SECURITY



End-to-end Geospatial Solutions

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

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



ANYONE CAN TAKE A PICTURE
WE TELL ITS STORY

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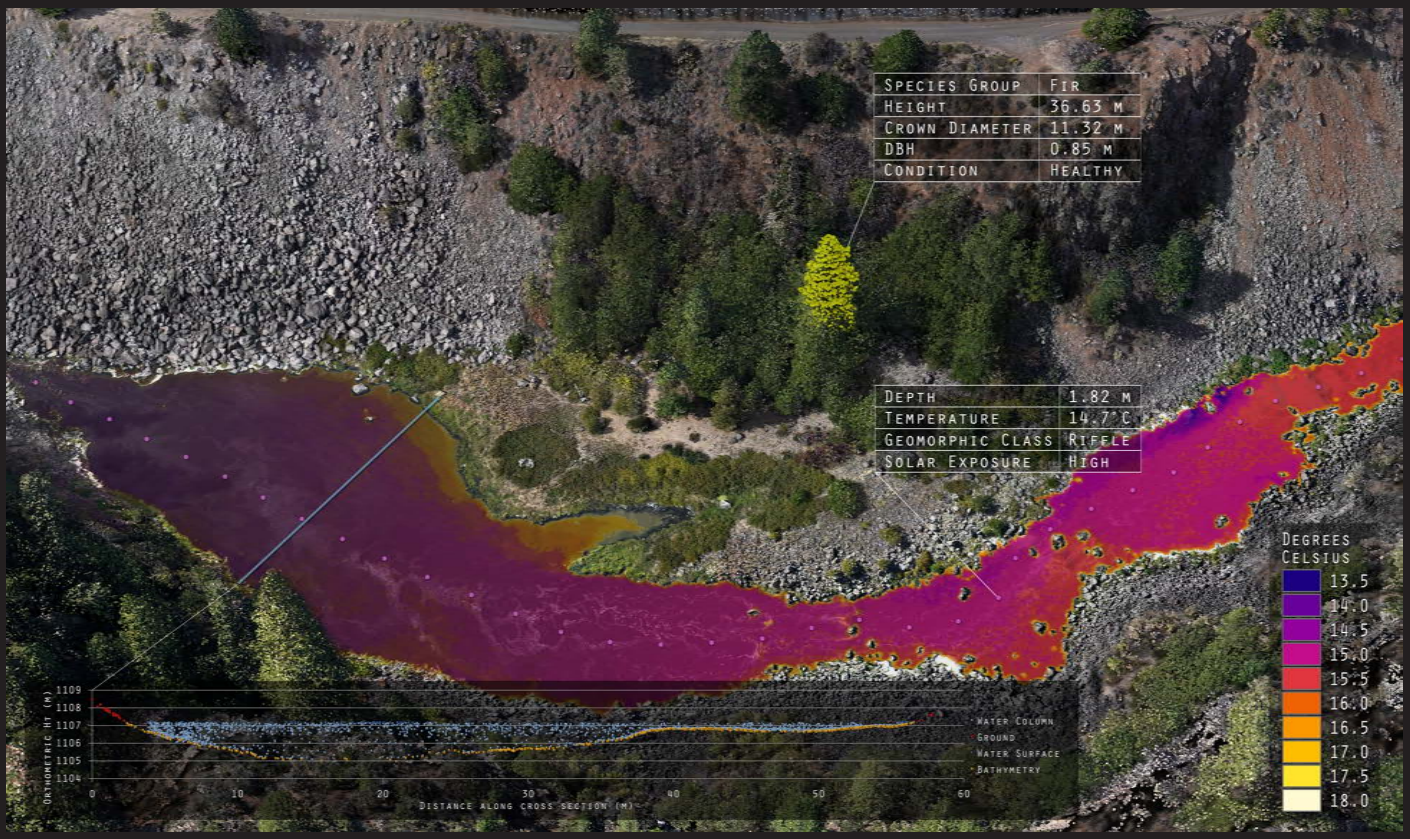

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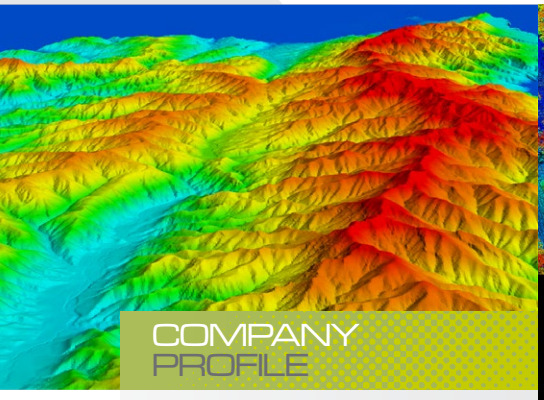

COMPANY PROFILE

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

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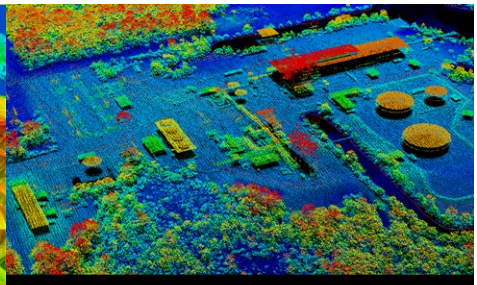
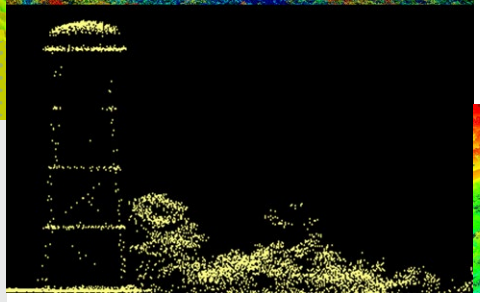
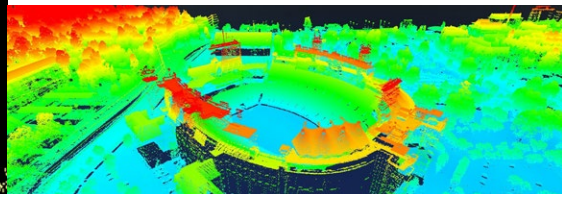




APPLICATIONS

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



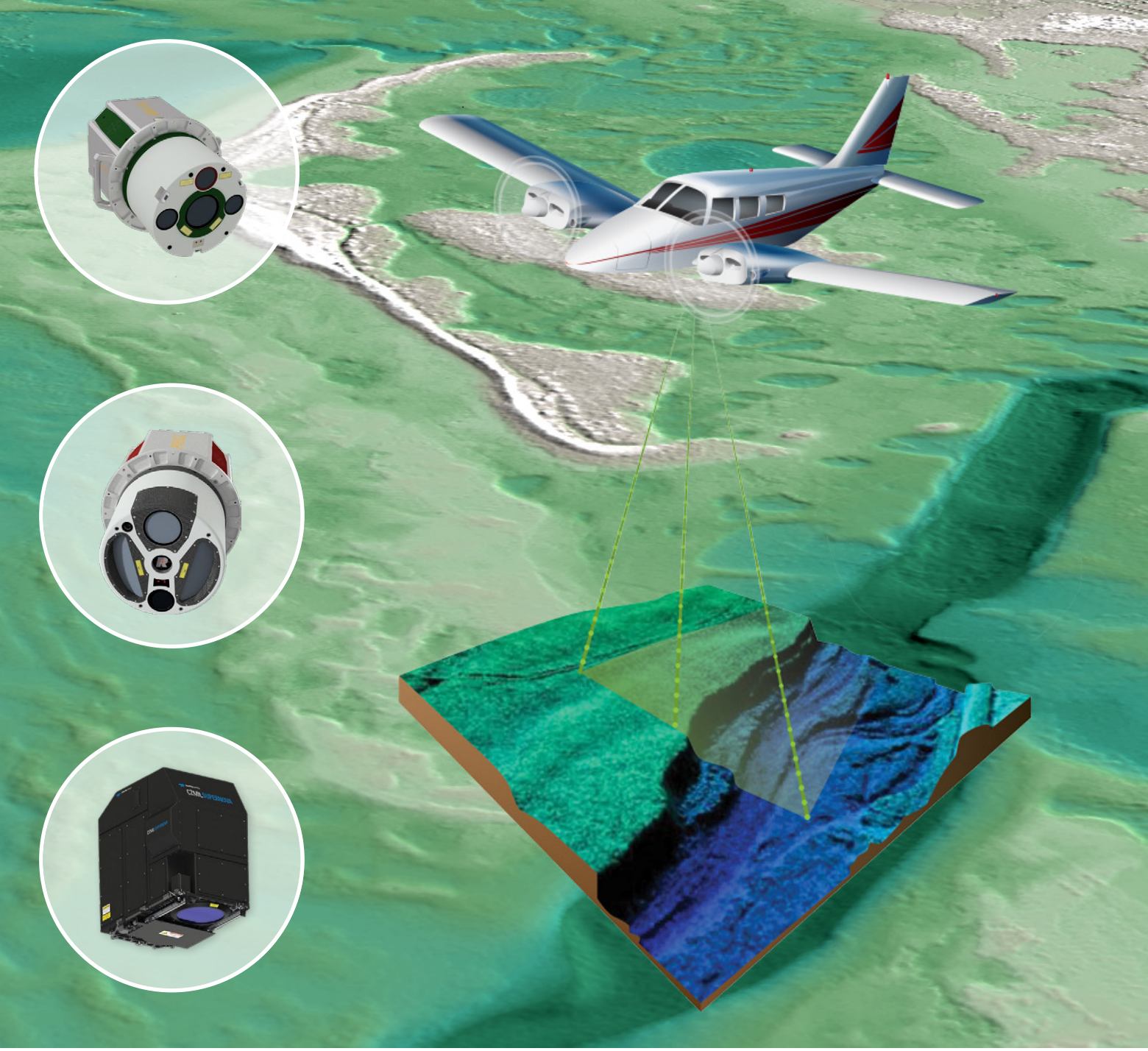
Dewberry's Geospatial and Technology Services

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

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

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

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



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Transformed Trajectories

Multi-story parking garage above underground parking.

Applanix strengthens integration, pushes processing boundaries

As an industry leader in mobile mapping solutions, Trimble Applanix is well known for its pioneering advances in the GNSS/inertial space for land, air and sea-based applications for a wide variety of industries. In the past year, the company has introduced several interesting and novel advances, including a high-accuracy navigation package and a lidar-based georeferencing optimization solution. Both innovations were put to work on a project in China with impressive results.

BY VICKI SPEED

Inside AVP mapping

NavInfo, China's leading location service and smart mobility solution provider, was tasked with mapping a large underground parking lot with roughly 1000 parking spaces. The resulting data will be used for automated valet parking (AVP), a sensor-based solution that automatically drives a car to a parking spot and then returns to a designated pickup point when authorized. Due to the tight space in the underground parking, the AVP is currently limited to vehicles equipped with autonomous driving capabilities.

The company has become a leader in the fields of navigation maps, dynamic traffic information, and customized connected vehicle solutions for passenger cars and commercial vehicles. NavInfo has relied on a variety of Trimble Applanix hardware products acquired through LEN, the Applanix representative in Mainland China, since 2017.

Guo Linxi, process development engineer for research and development at NavInfo, said, "Applanix products are high-accuracy with reliable performance, and the latest AP+ product line continues the product excellence."

Applanix hardware solutions are used by NavInfo's autonomous driving group, HD MAP, and many other departments. "Other companies can only provide relevant data-processing software or POS hardware separately, while Trimble Applanix provides a complete solution including hardware and software. Therefore, the Trimble Applanix product is definitely our first choice," added Linxi.

To be effective for AVP purposes, the underground parking garage map requires high accuracy to ensure that cars are parked with precision—in this case, point-cloud accuracy to within 10 cm. NavInfo opted for the Trimble AP+ 60 Land GNSS-inertial OEM system and the Applanix LiDAR QC Tools, a georeferencing cloud and trajectory adjustment software.

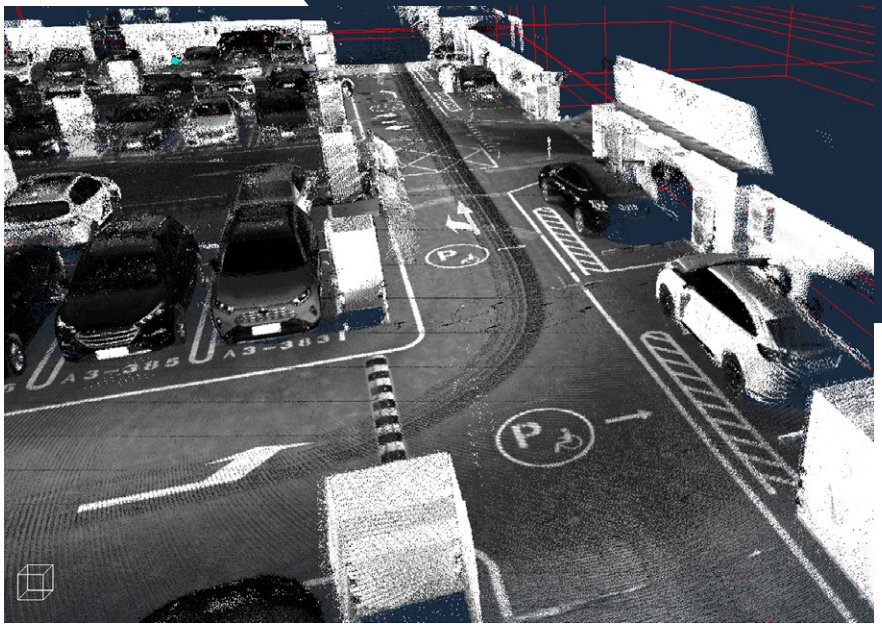
The Trimble AP+ 60 Land is a next-generation, embedded GNSS-inertial solution. What makes it particularly valuable for NavInfo's underground garage project is that it is small

Inside underground parking garage.

enough to easily integrate into most compact mobile mapping systems, and is configurable to meet the mapping, positioning and direct georeferencing accuracy demands of mapping and positioning applications in environments that are challenging for GNSS signals.

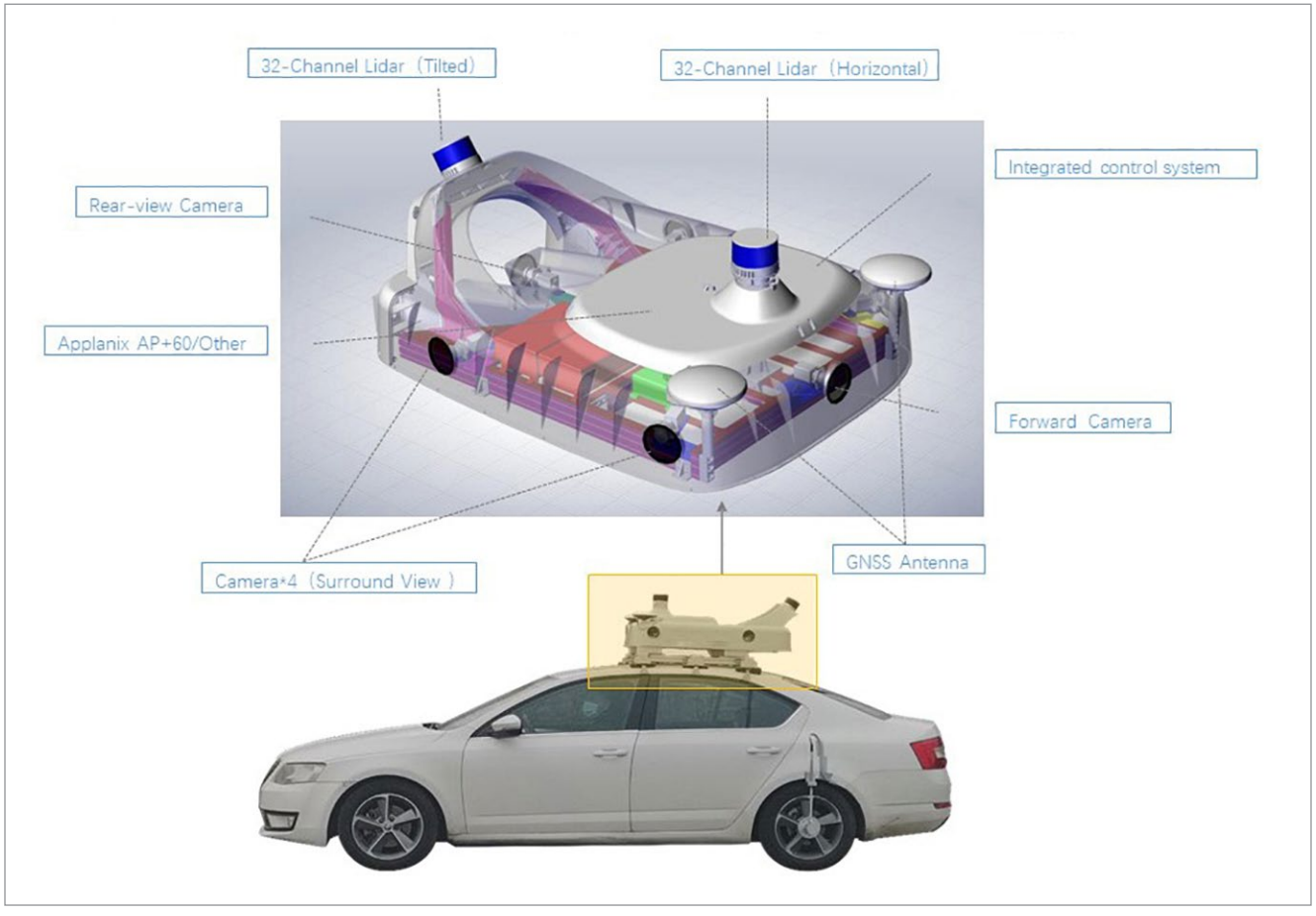
Besides its survey-grade GNSS/IMU sensors and distance measurement indicator (DMI), the Trimble AP+ 60 Land incorporates the all-new Applanix IN-Fusion+™ GNSS-aided inertial firmware featuring Trimble ProPoint™ GNSS, a GNSS measurement processing and correction methodology.

Anna Jarvis, product manager for land mobile mapping at Trimble Applanix, said, "This integrated GNSS/inertial navigation technology provides the highest level of navigation sensor integration, producing position and orientation measurements with an unequaled level of accuracy and robustness."



Corner of underground parking garage.

At the heart of the Applanix IN-Fusion+ technology is an advanced Kalman-filter architecture that incorporates sophisticated inertial and aiding



HD MAP data acquisition system: Type L
NavInfo mobile mapping vehicle.

sensor error models developed using the Applanix SmartCal technology and Trimble ProPoint GNSS.

In the case of the underground garage, data from inertial sensors is run through a navigation algorithm and fused with information from other sensors such as GNSS and the DMI to produce highly accurate, high-rate 3D measurements of the position, velocity, and orientation of a platform as it moves.

"It is an optimal method of blending the information of all measurement systems into a single solution," Jarvis continued. "In essence, this advanced technology takes advantage of each measurement technology and eliminates or significantly reduces individual limitations."

In addition, Trimble ProPoint GNSS leverages the latest developments in GNSS signal infrastructure and Trimble's high-precision Maxwell 7 receiver hardware to deliver improved positioning performance in challenging environments. It enables robust GNSS positioning performance under harsh tracking conditions, while its sophisticated signal filtering and error modeling means better protection against jamming, spoofing, and multipath interference.

For the underground parking garage mapping project, LiDAR QC Tools provide the final calibration and drift correction to the point cloud data.

QC connections

While LiDAR QC Tools have been available for the Trimble Indoor Mobile Mapping Solution (TIMMS) for many years, the same capabilities have only recently become available for airborne and land applications to optimize positioning accuracy in areas where GNSS coverage is limited, even when supported by inertial sensors or DMI.

Jarvis said, "Trimble Applanix has long offered our POSPac Photogrammetry tools for optimizing the application of

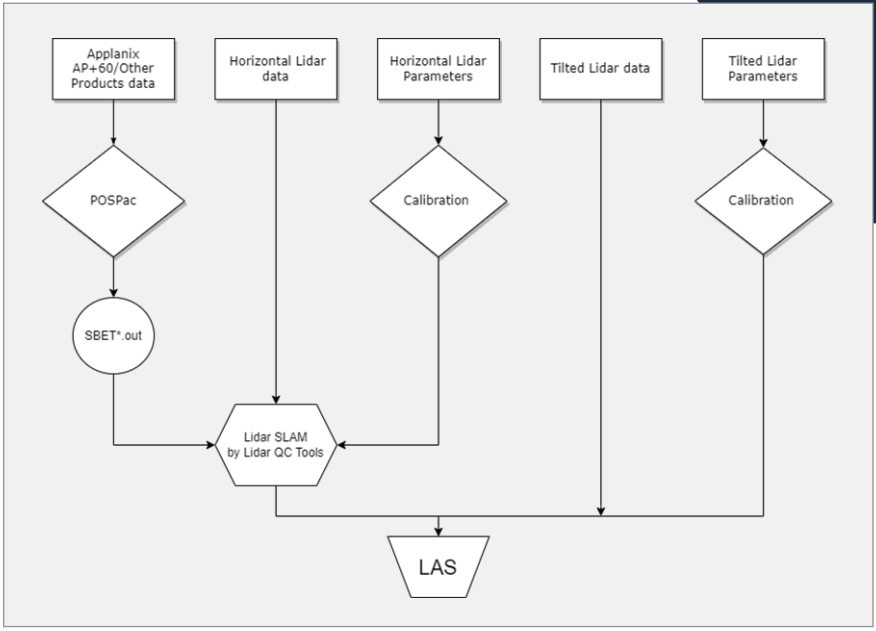
direct georeferencing with cameras. With the new LiDAR QC Tools, we are doing the same for lidar applications."

When a camera is installed with lidar, the lidar itself can be used as an aiding sensor to improve position accuracy of the GNSS-inertial trajectory. The LiDAR QC Tools rely on lidar SLAM (simultaneous localization and mapping) technology to create voxels or 3D pixels from the lidar data and match the overlap regions. The software then automatically runs an iterative least squares adjustment using the matched points to solve for the constant lidar boresight angles. It can also make corrections to position and orientation of the trajectory that is used to generate the points. For accurate multi-sensor integration, the boresight angles between the sensors must be known to the highest accuracy. The LiDAR QC boresight calibration tool solves this requirement for mobile mapping using lidar.

"LiDAR QC Tools is used to adjust the trajectory using the point cloud to correct any residual errors, after which it is used to generate a corrected exterior orientation to georeference any onboard camera or other sensor," Jarvis explained. "It makes direct range measurements to the structures around the vehicle, providing relative position changes of the vehicle. Those measurements can be used to correct the drift in the trajectory."

LiDAR QC Tools is an essential piece of NavInfo's underground parking garage project.

Wu Jiahua, process development engineer for research and development at NavInfo, explained, "We use LiDAR QC Tools to perform boresight calibration between IMU and lidar sensor, trajectory adjustment and point-cloud



Workflow of Lidar QC Tools.

generation in the LAS file format. Using the LiDAR QC Tools greatly improved the accuracy of the HD map in this super-large underground environment."

He continued, "The functionality of the LiDAR QC Tools has reduced our labor cost while increasing operational efficiency. Not only can it complete the automatic calibration of the lidar, but it can also perform trajectory improvement under GNSS-challenged environments."

The underground parking garage project started June 2022 and finished in December, with continuous optimization on the data-processing workflow ongoing.

Subscription evolution

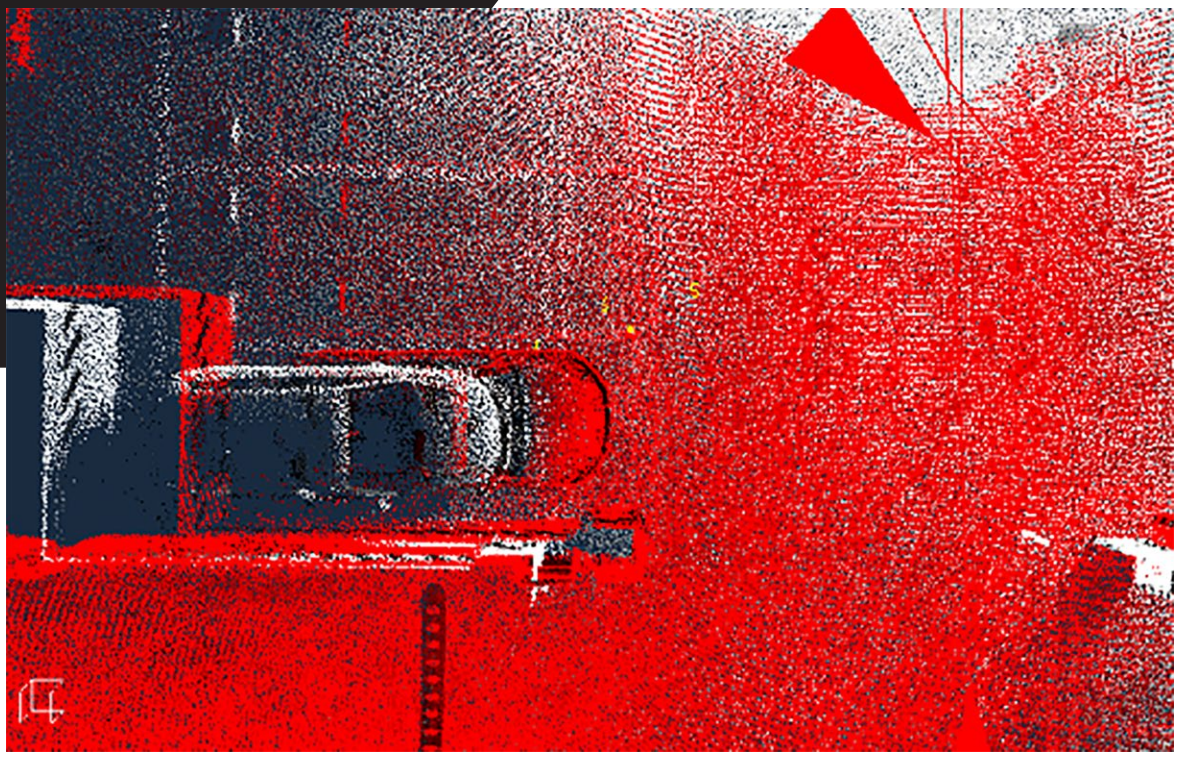
Applanix IN-Fusion+™ and LiDAR QC Tools are just two of the Trimble Applanix advances that have come onto the market in the past year.

Very recently, the company launched a brand new as-a-service product called the Trimble PX-1 RTX™ solution, which provides accurate and robust positioning and heading for commercial drone delivery applications.

Joe Hutton, director of inertial technology, land and airborne products, said, "We are excited about the commercial drone delivery market and think our high-accuracy RTX positioning and heading technology can be of great benefit to solving some of the problems that are limiting efficient operations."

Trimble PX-1 RTX leverages Trimble's CenterPoint® RTX corrections in a small, high-performance GNSS-inertial piece of hardware to provide real-time, centimeter-level positioning and highly accurate inertial derived true heading measurements.

Trimble PX-1 RTX has several unique features. It's ideal for accurate guidance and control in magnetically challenged environments thanks to its precise single antenna IMU heading. With Trimble CenterPoint RTX corrections



Comparison of results: Before Lidar QC Tools are applied, accuracy was 150 cm (left); after Lidar QC Tools, accuracy improved to 9 cm (right).

over satellite L-Band or NTRIP, there's no need for base stations. Further, the Applanix IN-Fusion+ multi-sensor aided inertial technology ensures consistent solution performance in all environments.

Hutton added, "This solution allows operators precise control of the drones during takeoff and landing in order to tackle more demanding operations in tight or partially obstructed spaces. It also minimizes operational risks from poor sensor performance or magnetic interference by ensuring greater positioning redundancy, especially important as commercial drone delivery operations venture into increasingly difficult, or challenging high-stakes environments in urban and suburban environments."

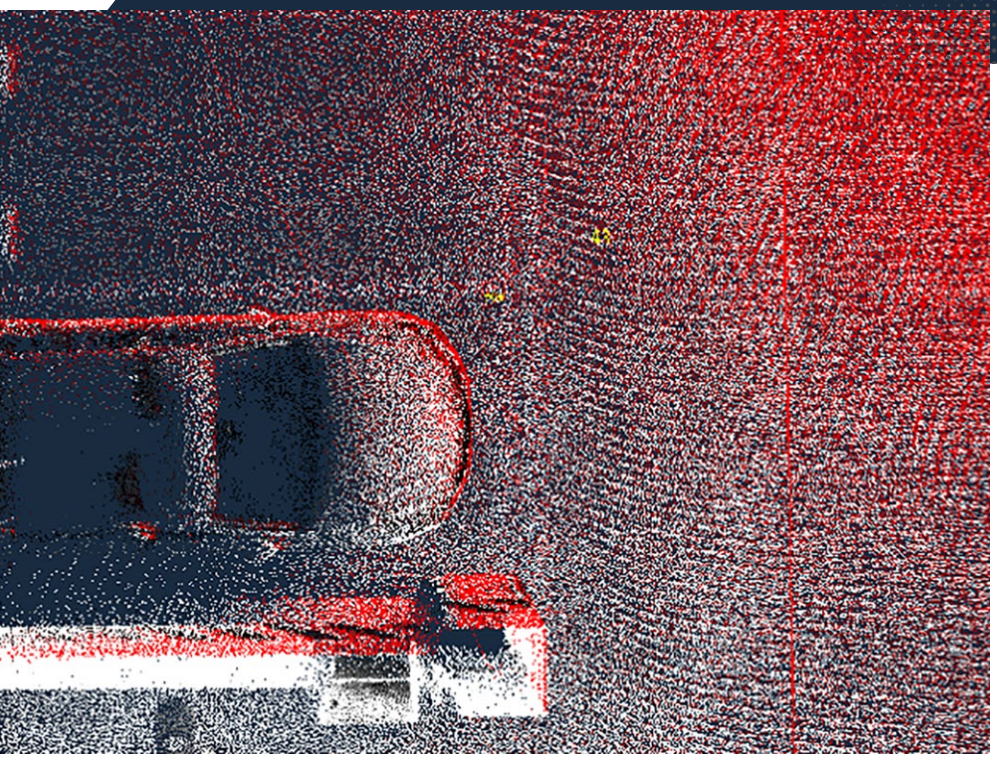
Post-processing progressions

One of the most significant developments is the introduction of POSPac 9, Applanix's next generation of post-processing software, which incorporates the Trimble ProPoint, IN-Fusion+ and the latest post-processed CenterPoint RTX technology (PP-RTX 2).

The new POSPac supports all the latest GNSS satellites, signals and frequency bands, and uses advanced multipath and outlier filtering to optimally fuse GNSS data into a robust and accurate aided-inertial position and orientation solution. Real-world results from more than 72 hours of dense urban-area data show that the new POSPac can achieve more than 100% position accuracy improvement versus POSPac 8 for mobile mapping applications. For UAV mapping applications, the PP-RTX 2 service with full BDS III support now achieves convergence to centimeter-level accuracy for short UAV trajectories virtually anywhere in the world.

POSPac Cloud is a cloud-based version of the Applanix POSPac software. The interface to the cloud service is via API, where data collection from Applanix hardware is processed through the internet. The software-as-a-service is available as a flexible pay-per-use model—and cybersecurity is top-of-mind.

Jarvis continued, "With 24/7 monitoring, cybercrime protection, and vulnerability checks, Applanix POSPac Cloud is designed with enhanced security so our users can work confidently."



Other Trimble Applanix partners have relied on land-based applications and have adopted the Applanix POS LV solution, a compact, fully integrated, turnkey position and orientation system, that also relies on integrated inertial technology to generate stable, reliable and repeatable positioning solutions.

The Fraunhofer-Gesellschaft, the world's leading applied research organization, is one such organization. The organization's Institute for Physical Measurement Techniques (IPM) is focused on developing and delivering optical measurement systems for different applications, including detailed mobile mapping solutions. Fraunhofer IPM is working with the leading European telecommunications company, Deutsche Telekom, to create precise maps of urban streets with detailed surface information to optimize the planning for new fiber-optic cables. To achieve this goal, Fraunhofer IPM custom built a measuring system utilizing four cameras and a lidar system. Enhanced location sensing was achieved using Trimble's Applanix POS LV to provide accurate georeferencing for road geometry, pavement inspection, GIS database and asset management, road surveying, and vehicle dynamics—all to a location accuracy of 1 cm.

In New Zealand, Data Collection Ltd (DCL) is using the Applanix POS LVX in its Road Measurement Data Acquisition System (ROMDAS®). ROMDAS equipment is frequently used to inspect airport runways and tarmacs for foreign object detection (FOD). The ROMDAS LFOD (Laser Foreign Object Detection) has improved airport tarmac surveying. These inspections can be performed with three people in a vehicle in less than two hours.

German-based Railergy, a transportation and solutions company, partnered with an international transport and logistics company to develop autonomous shunting (switching), a technique that will allow a locomotive to move cars into the positions without a driver or remote control. A key component for successful autonomous shunting is the Applanix POS LV direct georeferencing solutions. This solution eliminates the need for ground control points and speeds up mapping activities. With POS LV, Railergy can create an accurate map of the rail yard in an automated, quick and efficient manner and accurately track the live operation in real-time. Railergy is on schedule to deliver the first autonomous locomotive in 2024.

Hutton concluded, "Our focus is and remains upon providing the best possible georeferencing solutions for our customers so they can deliver the best possible mapping and positioning solutions to their customers. We listen to their needs and are continuously investing and adapting our technology and products to ensure they remain competitive. We view our customers as partners and our products are made to be part of their solutions."

Vicki Speed has been a freelance writer specializing in the AEC space for over 25 years. She has an interest in and passion for all things about the industry from contracts and risk management to people, processes, equipment and, especially, technology.

LIDAR LEADER AWARDS
OUTSTANDING INNOVATION

GEOCUE

COMPANY PROFILE

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

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

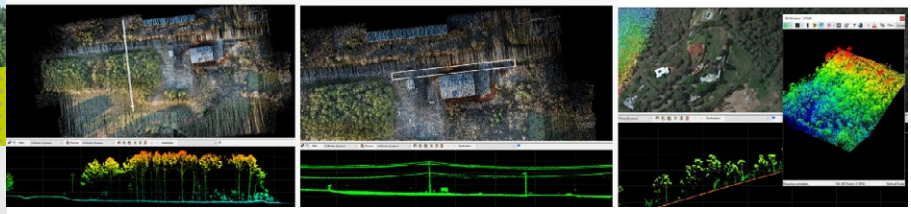
GEOCUE

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

geocue.com

APPLICATIONS

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



The Leaders in LiDAR Mapping Hardware & Software Since 2003

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

Fly, Process, Deliver—All in One Solution

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

Utility-Grade to Survey-Grade 3D Imaging

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

LP360 LiDAR & Photogrammetry 3D Point Cloud software

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

LP360 DRONE

Maximize Your L1 & L2 Data with this Special Offer from LP360 Drone

Enhance the Accuracy and Efficiency for your Drone Surveying

Are you using the DJI Zenmuse L1 or L2 LiDAR and RGB solution to capture 3D data for aerial surveying? Then take that data to the next level with LP360 Drone LiDAR & photogrammetry 3D point cloud software.

With LP360 Drone you can process, analyze, and maximize your L1 & L2 drone survey data, creating enhanced and highly accurate deliverables.

The fully integrated workflow of LP360 Drone lets you Fly, Optimize and Deliver fully processed data into actionable results. Learn how you can get the most out of your L1 data with LP360 Drone.

Get the most out of your L1 & L2 Data with LP360 Drone

- Manage your coordinate system (geoid, grid to ground, local site, datum and epoch change)
- Leverage LP360 powerful 3 synchronized viewing windows and Image Explorer tool
- QC/QA your data with Automatic Ground Control Detection and 3D Correction
- Access all the other advanced tools such as Smoothing, Automated Outlier Removal, Automatic Classification, Break lines, DTM and Contour Generations, export to CAD formats, volumetric calculations, powerlines encroachment tools and much more
- Customize / define your own workflow with the new GUI
- Go further with unique LP360 Cloud Extension (optional add-on) to store, search, share and stream your data with any LP360 Desktop

Scan to learn more >

SPECIAL OFFER!

Get LP360 Cloud to Make Your Geospatial Work Easier

For any LP360 order in February, get **3 months of free access** to LP360 Cloud and Cloud Starter

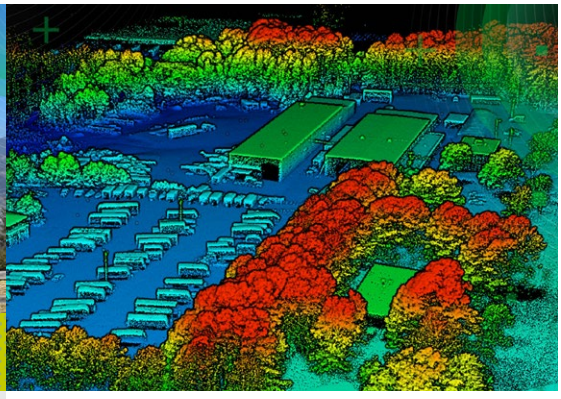
LP360 Cloud is an ever-growing collection of cloud-based tools and resources that will make it easy for you to manage, archive, share and collaborate on geospatial projects.

As is true with all LP360 software, we are always building it around you; see below for the latest that LP360 Cloud has to offer:

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

TOPODRONE

COMPANY PROFILE



APPLICATIONS

- MAPPING
- SURVEYING
- 3D MODELING
- BATHYMETRY
- FOREST MONITORING
- AGRICULTURE
- CONSTRUCTION
- MINING

TOPODRONE is a Swiss based designer and manufacturer of high-precision surveying equipment for installation on UAVs, vehicles and backpacks. TOPODRONE's hardware (LiDARs, high resolution cameras, PPK and bathymetry devices) are used for mapping and 3D modeling. Application areas include but are not limited to forest and agricultural monitoring, construction and urban planning, and bathymetry. TOPODRONE's advanced post-processing software provides users with easy-to-use innovative data processing workflows for automatic data generation, georeferencing and alignment using GNSS and IMU data post processing, and SLAM algorithms.

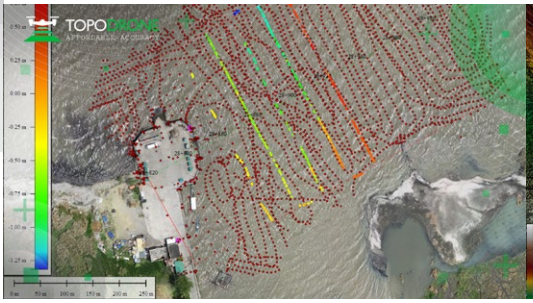
TOPODRONE
AFFORDABLE ACCURACY

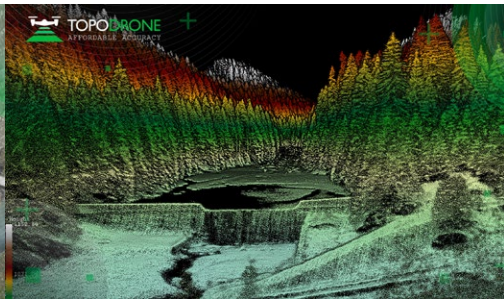
TOPODRONE, Rue de la Gare 13,
1820 Montreux, Switzerland
+41 21 588 02 11
info@topodrone.com

topodrone.com

TOPODRONE Mission is to Provide Affordable and Reliable Solutions for Surveyors All Over the World

TOPODRONE offers a wide range of multipurpose surveying hardware and software both developed in-house and through upgrading partner solutions. The company focuses on the production and distribution of PPK solutions, photogrammetry payloads, LiDAR-based equipment, and UAV-based bathymetry integrations. In-house R&D includes equipment to enable PPK on small-size UAVs, high resolution mapping and multispectral photogrammetry payloads, survey grade LiDAR systems and AQUAMAPPER to perform bathymetric surveying. All TOPODRONE photogrammetry and LiDAR hardware can be used together and can be mounted on a UAV, a car or a backpack while collected data is easily processed with TOPODRONE PPK and LiDAR post processing software. TOPODRONE AQUAMAPPER is an addition to the TOPODRONE hardware family which performs accurate underwater studies. The compatibility of data collecting and processing approaches make it possible to accumulate and synchronize all types of data: aerial, terrestrial, bathymetric.

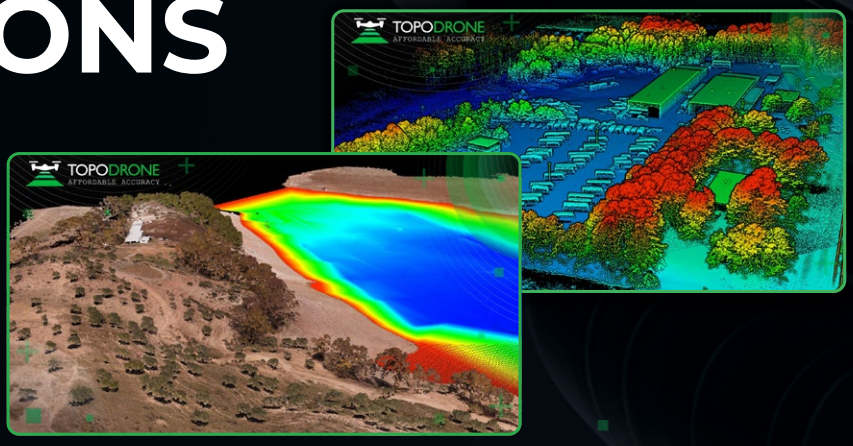




TOPODRONE
AFFORDABLE ACCURACY

GEO WEEK

COMBO SURVEYING SOLUTIONS



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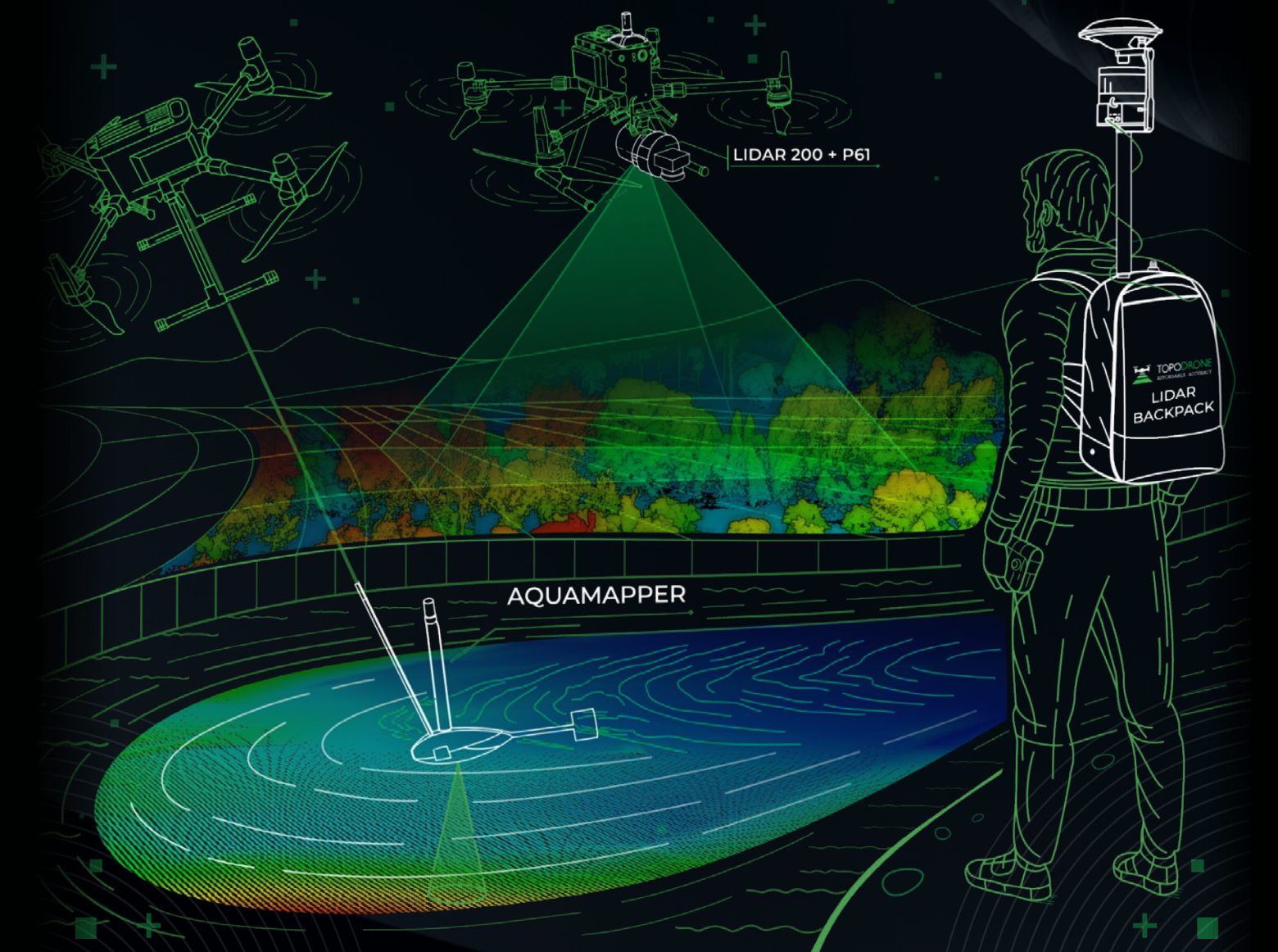

RIEGL

APPLICATIONS

- AIRBORNE
- BATHYMETRIC
- MINING
- MOBILE
- INDUSTRIAL
- TERRESTRIAL
- UNMANNED
- WIDE-AREA

COMPANY PROFILE

With more than 40 years of experience in the research, development and production of laser rangefinders, distancemeters and scanners *RIEGL* delivers proven innovations in 3D.

The combination of *RIEGL's* state-of-the-art hardware for terrestrial, industrial, mobile, airborne, bathymetric and UAV-based laser scanning with appropriate, equally innovative *RIEGL* software packages for data acquisition and processing results in powerful solutions for multiple fields of application in surveying.

RIEGL has always been committed to delivering the highest performance, quality, reliability, and longevity of all its products and services, and strict adherence to applicable international standards is a priority.

It is our ambition to perfectly fulfil measurement tasks fully satisfying the customers' expectations worldwide.

Innovation in 3D

RIEGL is an international leading provider of cutting-edge technology in airborne, mobile, terrestrial, industrial and unmanned laser scanning solutions for applications in surveying.

RIEGL has been producing LiDAR systems commercially for over 40 years and focuses on pulsed time-of-flight laser radar technology in multiple wavelengths.

RIEGL's core Smart-Waveform technologies provide pure digital LiDAR signal processing, unique methodologies for resolving range ambiguities, multiple targets per laser shots, optimum distribution of measurements, calibrated amplitudes and reflectance estimates, as well as the seamless integration and calibration of systems.

RIEGL's Ultimate LiDARTM 3D scanners offer a wide array of performance characteristics and serve as a platform for continuing Innovation in 3D for the LiDAR industry.

From the first inquiry, to purchase and integration of the system, as well as training and support, *RIEGL* maintains an outstanding history of reliability and support to their customers.

Worldwide sales, training, support and services are delivered from *RIEGL*'s headquarters in Austria and in the USA; main offices in, Japan, China, Australia, Canada and the UK; and a worldwide network of representatives.

Founded 1977
240+ Employees
Horn, Austria
Winter Garden, FL USA

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RIEGL UAV
LiDAR SENSORS & SYSTEMS

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FOR YOUR SPECIFIC SURVEYING MISSION!

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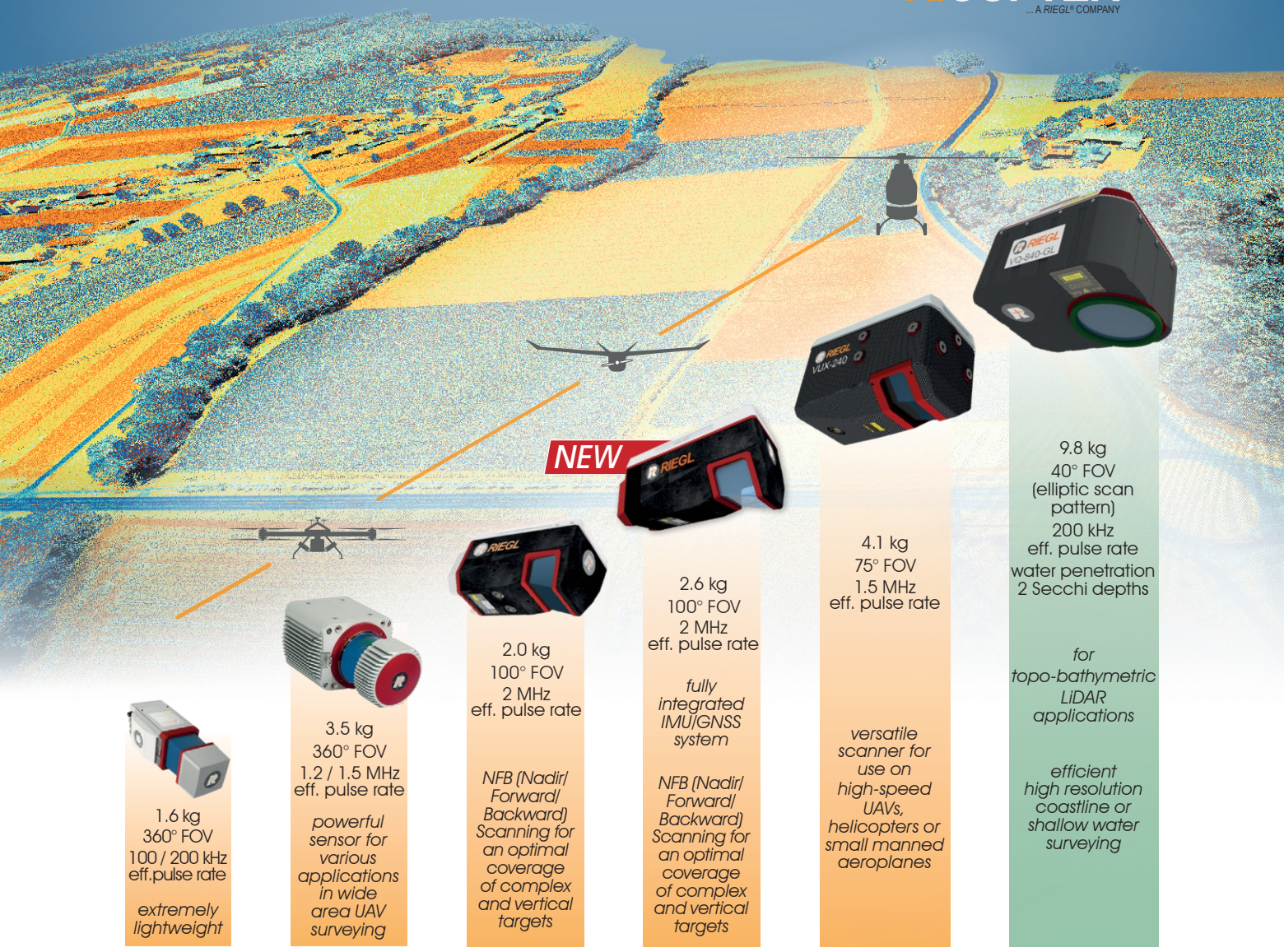
... A RIEGL® COMPANY



miniVUX-1UAV miniVUX-3UAV	VUX-1UAV[22] VUX-1LR[22]	VUX-120[23]	VUX-160[23]	VUX-240	VQ-840-GL
1.6 kg 360° FOV 100 / 200 kHz eff.pulse rate *extremely lightweight*	3.5 kg 360° FOV 1.2 / 1.5 MHz eff. pulse rate *powerful sensor for various applications in wide area UAV surveying*	2.0 kg 100° FOV 2 MHz eff. pulse rate *NFB (Nadir/ Forward/ Backward) Scanning for an optimal coverage of complex and vertical targets*	2.6 kg 100° FOV 2 MHz eff. pulse rate *fully integrated IMU/GNSS system* *NFB (Nadir/ Forward/ Backward) Scanning for an optimal coverage of complex and vertical targets*	4.1 kg 75° FOV 1.5 MHz eff. pulse rate *versatile scanner for use on high-speed UAVs, helicopters or small manned aeroplanes*	9.8 kg 40° FOV (elliptic scan pattern) 200 kHz eff. pulse rate water penetration 2 Secchi depths *for topo-bathymetric LiDAR applications* *efficient high resolution coastline or shallow water surveying*

for applications using low-flying small or mid-sized multi-rotor UAVs
e.g. mining, topography, forestry, landslide and avalanche monitoring

for applications using fixed-wing UAVs
e.g. corridor mapping, city modeling

for applications using higher-flying large UAVs or helicopters
e.g. mapping with the need of detailed high-resolution data

Explore the full portfolio of proven RIEGL LiDAR sensors and systems
www.riegl.com

RIEGL®

Stonex USA

COMPANY PROFILE

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

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

The products offered by STONEX include:

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

STONEX U.S.A.

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603-715-5771
sales@stonexamerica.com

stonexamerica.com

Stonex Headquarters—Italy
Viale dell'Industria 53
20037 Paderno Dugnano (MI) – Italy
+39 02 78619201
info@stonex.it

stonex.it

APPLICATIONS

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

Stonex Laser Scanners are the perfect companions for your field surveys

Compact, Easy, Reliable

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

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

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

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

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

STONEX U.S.A.

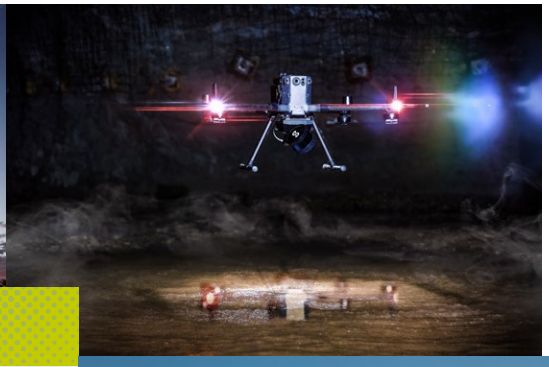
Stonex USA | 54 Regional Dr | Concord New Hampshire 03301
For a Stonex dealer near you contact us:
Phone: 603-715-5771 | sales@stonexamerica.com

LIDAR SOLUTION
X FLY

www.stonexamerica.com

Frontier Precision / Frontier Precision Unmanned

(A Division of Frontier Precision)



APPLICATIONS

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

COMPANY PROFILE

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

FRONTIER PRECISION
How You Measure Matters

FRONTIER PRECISION UNMANNED
A Division of Frontier Precision

1713 Burlington Drive
Bismarck, ND 58504
howyoumeasurematters
@frontierprecision.com

frontierprecision.com
frontierprecision.com/unmanned

Precision Beyond Bounds

Frontier Precision Unmanned has the latest innovations in drone aircraft and sensors to fit your job or application. We offer industry-leading products and software from Ascent Aerosystems, Autel, Censys Technologies, DJI Enterprise/DJI Agriculture, Freefly Systems, Flybotix, Hylio, Inspired Flight, Parrot, Quantum-Systems, Skydio, Watts Innovations, YellowScan, Emesent, AgEagle, Phase One, FLIR, Pix4D, and many others ensuring you get the right product for the right UAS application. UAS applications include geospatial surveying & mapping, agriculture, construction, energy, forestry, infrastructure, mining, mosquito & vector control, oil & gas, and public safety.

With LiDAR, your first mapping and survey point should be with us. Our staff has the knowledge and real-world experience to help you implement LiDAR. Just as important, with our range of LiDAR technology, you'll find a solution that works perfectly with your budget.

Use the industry's leading-edge technology without committing long-term capital to technology that may not have a long-term fit. The expert team at Frontier Precision UAS/Imaging Services can help when you have a need for mobile/static scanning or UAS services, but lack the expertise or equipment to meet the requirements of the job. Frontier Precision Unmanned offers data-driven professional services for aerial surveying and photogrammetry applications using unmanned aircraft systems. We're expanding operations to include additional drones, sensors, and platforms to accommodate your data needs. Whether you are interested in operating drones yourself, or sub-contracting a service provider to collect data for a project, Frontier can help you incorporate this exciting technology into your workflow to collect high-precision aerial data.

FRONTIER PRECISION UNMANNED

Frontier Precision has the latest LiDAR, Photogrammetry, & Remote Dock innovations to fit your job or application.

Our staff has the knowledge and real-world experience to help you select the solution that's best for you and the training to make you more proficient and profitable.

YellowScan

The YellowScan LiDAR UAV delivers the highest level of accuracy and density for real-time georeferenced point cloud data.

emesent

Emesent automates the collection and analysis of data in challenging GPS-denied environments, delivering revolutionary efficiency, safety, and operational insights for the industry.

INSPIRED FLIGHT
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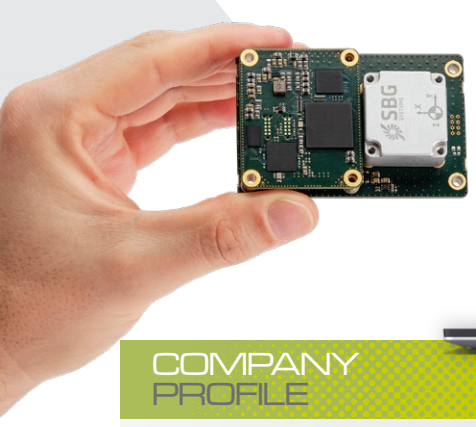
SBG SYSTEMS



APPLICATIONS

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

COMPANY PROFILE

SBG Systems is a fast-growing supplier of miniature, high-performance, and innovative motion sensing solutions. SBG Systems is headquartered in Carrières-sur-Seine, France, and operates in North America from its subsidiary in Santa Anna, CA, and in Asia with its subsidiary in Singapore. SBG Systems offers a complete line of inertial sensors, such as Attitude and Heading Reference System (AHRS), Inertial Measurement Unit (IMU), and Inertial Navigation Systems (INS), based on the state-of-the-art MEMS technology. This technology combined with advanced calibration techniques offers miniature and low-cost solutions while maintaining a very high performance at every level. Our sensors are ideal for projects such as unmanned vehicle control, antenna tracking, camera stabilization, and all surveying applications. From hydrography to mobile mapping and aerial cartography, SBG Systems offers a complete solution including the IMU, PPK software, and services.

SBG SYSTEMS

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

sbg-systems.com

SBG Systems Unveils Quanta Plus

The Next-Gen OEM GNSS-Aided INS

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

Quanta Plus: Optimized SWaP and Stellar Performance in Harsh Environments

Quanta Plus is engineered to deliver accurate and reliable navigation data even in the most demanding environments. It combines a high-performance miniature tactical IMU with a GNSS receiver that is resilient to harsh covering conditions, providing RTK fixes even in challenging situations (0.015° roll/pitch, 0.04° heading, 1cm positioning in RTK). The system boasts a wide range of features to make it easy to use and customize for various applications and features a built-in datalogger, ethernet interface for seamless integration, and a user-friendly web configuration UI for simple setup and control.

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

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

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

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

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

SBG SYSTEMS

High-Performance INS Solutions for Surveying Applications

NEW QUANTA SERIES

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

Quanta Micro

Quanta Plus

Quanta Extra

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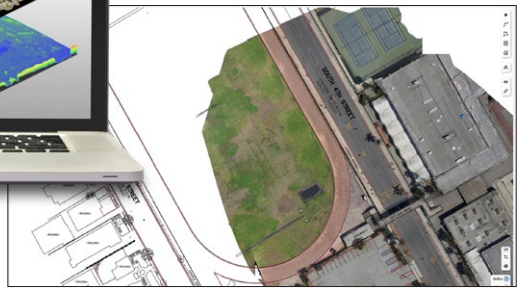
Carlson Software

APPLICATIONS

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



COMPANY PROFILE

Carlson Software has innovated for the land development and mining industries with software and hardware solutions built to work for the clients that depend on them every day. As a one-source solution, we provide CAD design software, field data collection, and laser measurement products for the surveying, civil engineering, GIS, and construction industries.

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

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

33 East 2nd Street
Maysville, KY 41056
606 564 5028
info@carlsonsw.com

carlsonsw.com

Integrated Photogrammetry + LiDAR Solutions

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

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

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

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

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

Whether you're working with public LiDAR data, fly your own UAV, or work with terrestrial scanner files, Carlson's industry-proven solutions provide the workflow options to produce the deliverables you need for your clients.

Carlson Software for
Photogrammetry + LiDAR
Bridging the Gap Between UAVs and CAD

Carlson PhotoCapture

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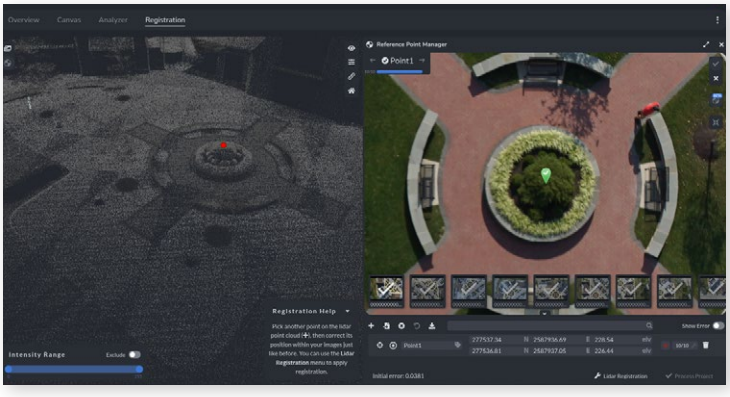

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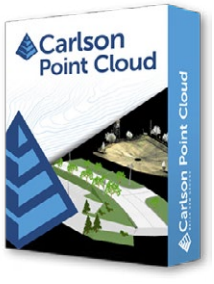

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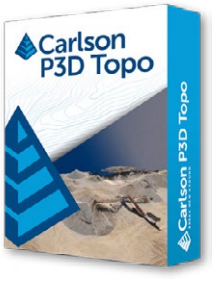

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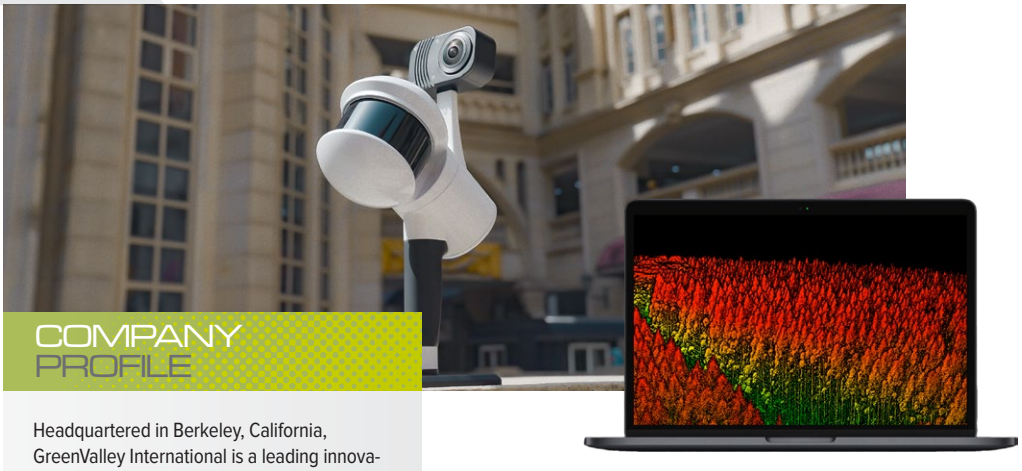

COMPANY PROFILE

Headquartered in Berkeley, California, GreenValley International is a leading innovator of 3D mapping technologies. We provide a wide range of advanced aerial, terrestrial, and mobile LiDAR surveying and mapping hardware systems, as well as cutting-edge software and service solutions. we strive to bring to our customers the most effective products that will get the job done.

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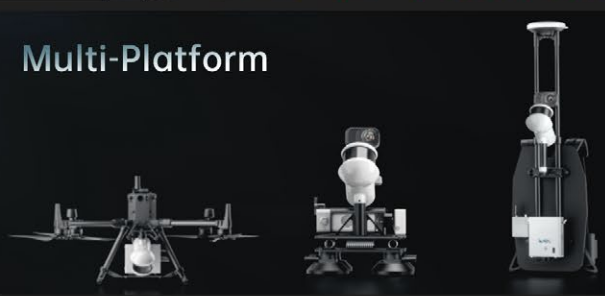

Nayegandhi, *continued from page 48*
requirements for improved topographic and bathymetric elevation data, estimate the benefits and costs of meeting these requirements, and evaluate multiple national enhanced program implementation scenarios. The goals of this study were to capture inland, nearshore, and offshore topographic and bathymetric elevation data requirements and benefits and understand how those requirements and benefits dovetail in the nearshore coastal zone. The study was comprehensive with a total of 1,352 Mission Critical Activities (MCA) reported by study respondents from 45 federal agencies, 56 states and territories, and 58 non-governmental organizations. The 3D Nation Study identified $3.6 billion in annual benefits for inland, nearshore, and offshore bathymetry that could be realized if all needs were met.

In 2022, NOAA published an analysis of publicly accessible bathymetric data holdings within U.S. coastal, ocean, and Great Lakes waters to the outer limit of the Exclusive Economic Zone (EEZ). The analysis looked at all modern (post 1960) bathymetric data holdings at NOAA's National Centers for Environmental Information (NCEI) and Office for Coastal Management (OCM). Actual soundings of multi-beam data (raw and processed), single-beam data (>1960), hydrographic surveys (>1960), bathymetric lidar, and crowdsourced bathymetry were included. The results showed that 52% of the US (and its territories) did not have a single sounding (measurement) within a 100-meter grid cell, and a large portion of the 48% area that is mapped can be considered "minimally mapped" with less than two soundings per 100 square meters and up to 60 years old. There is reason to believe that hydrography, in the U.S. and around the world, is in a state of crisis regarding the ability of professional hydrographic organizations to provide the needed and desired products within their budgets and in a timely manner. Conversely, the use of coastal areas by commercial and recreational concerns is growing at a rapid pace. Coastal zone engineers and managers need coastal bathymetric data for a wide variety of engineering and environmental applications. The need for high-resolution bathymetry data is real and requires the use of multiple mapping technologies to achieve full coverage.

> "In shallow depths the cost of vessel-based approaches is 10x higher if the goal is to obtain 'wall to wall' coverage."

Traditionally, the hydrographic community and the topographic community have operated in their own way—the hydrographic community has focused on vessel-based sonar/acoustic methods whereas the topographic community has used airborne lidar and even photogrammetry to derive land elevations. These vessel-based methods include the use of a single-beam echo sounder (SBES) or multi-beam echo sounder (MBES) systems to derive water depths. The hydrographic community has traditionally based its elevations on the tidal datum whereas the topographic community has used orthometric datums. The difference in reference datum manifests most at the land/water interface, often due to the varying definition for "shoreline" which can have significant scientific, engineering, social, economic, legal, and safety implications. The use of Airborne Lidar Bathymetry (ALB) helps bridge this divide.

Based on over several decades of operations, ALB (often referred to as airborne topobathymetric lidar) has proven to be an accurate, cost-effective, rapid, safe, and flexible method for surveying in shallow water and on coastlines where sonar systems are less efficient and can even be dangerous to operate. However, topobathymetric lidar has faced three basic challenges: the physics of light traveling through different media (air and water) and the ability of the lidar pulse to consistently reflect off the water surface and bottom; the reflectivity of the submerged bottom; and water column turbidity resulting from dissolved particulate/organic matter and suspended sediments, which is recognized to have an important role in obscuring the bathymetric ground. Inland waterways, known for dark, muck-covered bottoms, combined with tannic, dark waters, make for exceptionally challenging conditions for surveying with ALB sensors. However, the cost of operations for ALB systems are often 15-30% of the standard vessel-based survey cost, depending on location, depth, and survey density. In shallow depths the cost of vessel-based approaches is 10x higher if the goal is to obtain "wall to wall" coverage.

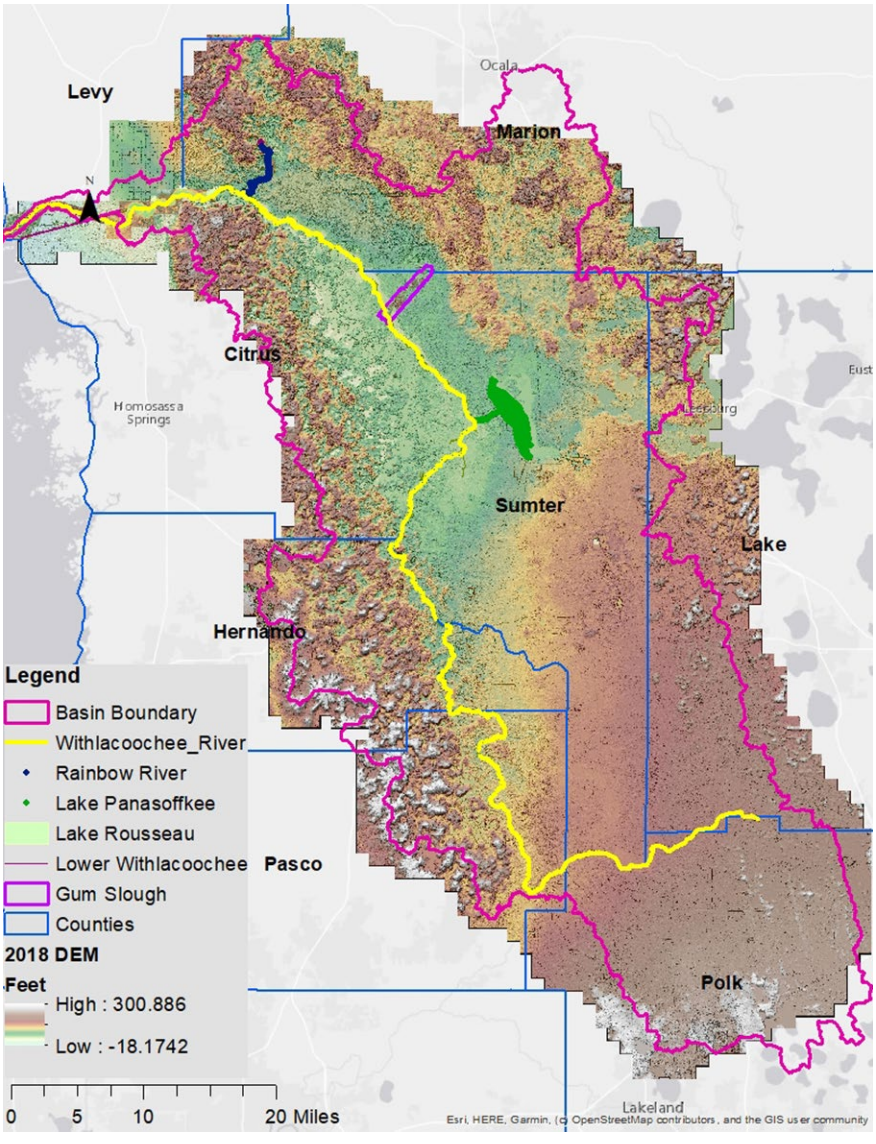

Figure 2: The "fly lidar first, fill-in gaps with sonar" philosophy was successfully implemented for the Lower Withlacoochee Watershed merged DEM by Dewberry.

Given all these considerations, there is a need for the use of combined technologies to achieve complete bathymetry coverage from the shoreline to offshore. Using a "fly lidar first, fill-in with sonar" philosophy has enabled the most efficient use of these airborne and vessel-based technologies (**Figure 1**). Dewberry has conducted numerous ALB surveys ranging from the Great Lakes, to rivers in Virginia, to the coastal environments and watersheds in Florida. We applied a "fly lidar first, fill-in with sonar" approach to complex projects such as the Withlacoochee River Minimum Flows and Levels (MFL) survey. Based on this general approach, topobathymetric lidar data were collected using the Coastal Zone Mapping and Imaging Lidar (CZMIL-SuperNova) sensor. Any gaps in the data were then filled in using either existing or newly collected multi- and single-beam, crewed and un-crewed surface vehicle sonar, and conventional GPS/Pole-soundings to construct and ground-truth a seamless terrestrial-hydrographic (hydrospatial) DEM. A similar approach is currently being used by Florida Department of Environmental Protection (FDEP) for the Florida Seafloor Mapping Initiative. The project is separated into three phases. Phase one focuses on using topobathymetric lidar to collect bathymetry to the 20-meter isobath. This topobathymetric lidar phase spans approximately 58,000 km^2. Phase two will focus on collecting MBES data to fill in the gaps resulting from the topobathymetric lidar collection activity, thereby resulting in the most efficient data collection methods and significant cost savings to FDEP. Phase 3 will focus on using MBES data for water depths between 20 meters and 200 meters, where the vessel-based technology is most efficient.

The creation of final seamless DEM using multiple data sources requires careful consideration of any offsets / gaps in the data and how they will be merged. The final seamless DEM for the Withlacoochee River model domain (**Figure 2**) was constructed using each data source to its fullest extent. In some cases, statistical kriging was used to densify the single-beam profiles, while in other cases, geometric smoothing techniques were used.

Amar Nayegandhi, Senior Vice President, Dewberry, leads the firm's geospatial and technology services team and technology solutions market segment.

AMAR NAYEGANDHI

The quest for "wall-to-wall" coverage for hydrospatial applications

The benefits of a "fly lidar first, fill-in with sonar" philosophy to obtain full bathymetry coverage

Over the past few decades, airborne topographic lidar has been the "go to" technology to create high-resolution digital elevation models (DEMs) of land surfaces. Advances in laser ranging, inertial measurement units (IMUs), and Global Navigation Satellite System (GNSS) technology have resulted in higher resolution and more accurate DEMs, improved bare-earth surface under vegetation, and better definition of above-ground features over a regional scale. These technology improvements have enabled the near completion of the USGS 3D National Elevation Program (3DEP) with 96% of the nation mapped with Quality Level 2 (QL) or better lidar topography data.

The need for high-resolution bathymetry data in the nearshore coastal zone is well documented in a recent study[1] completed by Dewberry for NOAA and USGS. The 3D Nation Elevation Requirements and Benefits Study was performed to document national

continued on page 46

1 dewberry.com/services/geospatial-mapping-and-survey/3d-nation-elevation-requirements-and-benefits-study

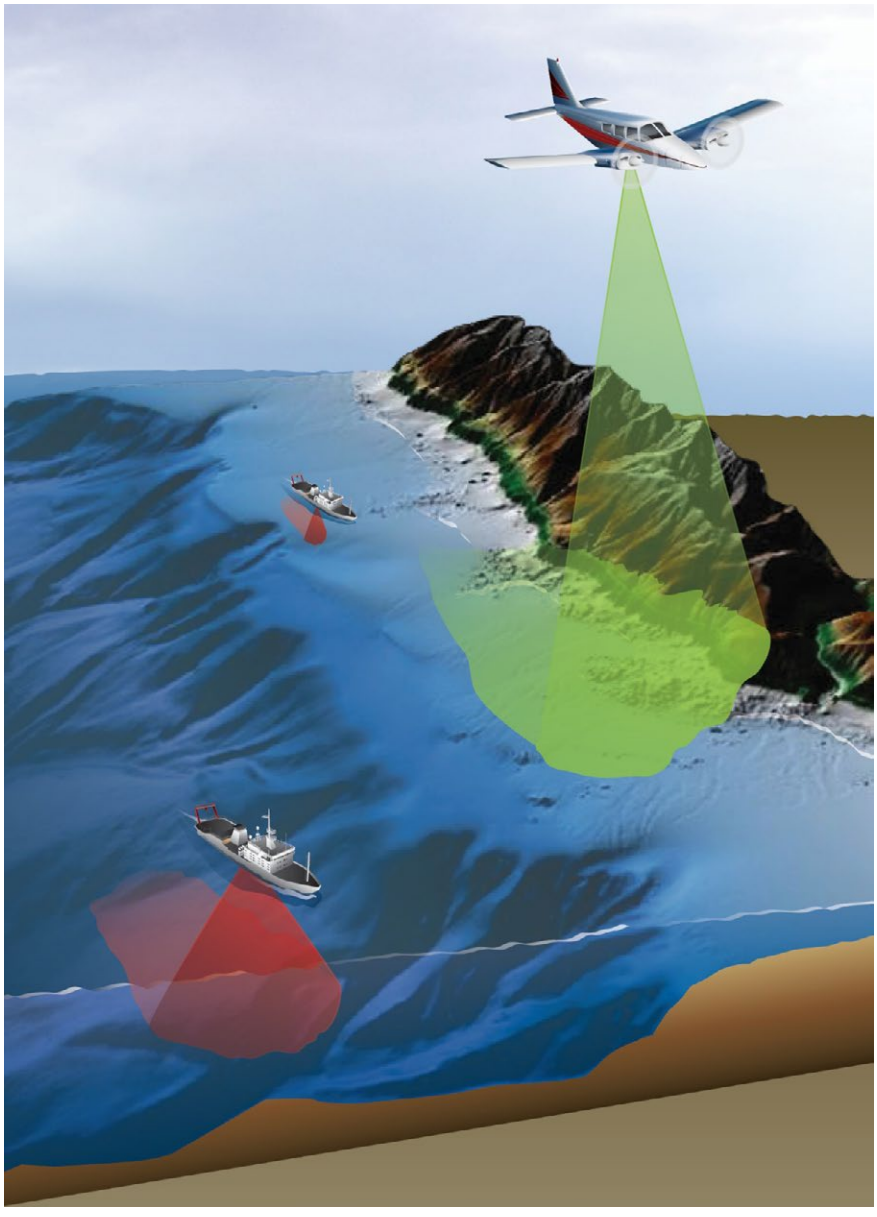

Figure 1: The collection of airborne lidar bathymetry (ALB) data in the nearshore zone followed by vessel-based MBES collection is the most efficient method to derive submerged topography.

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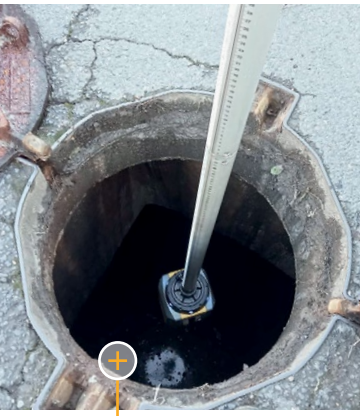

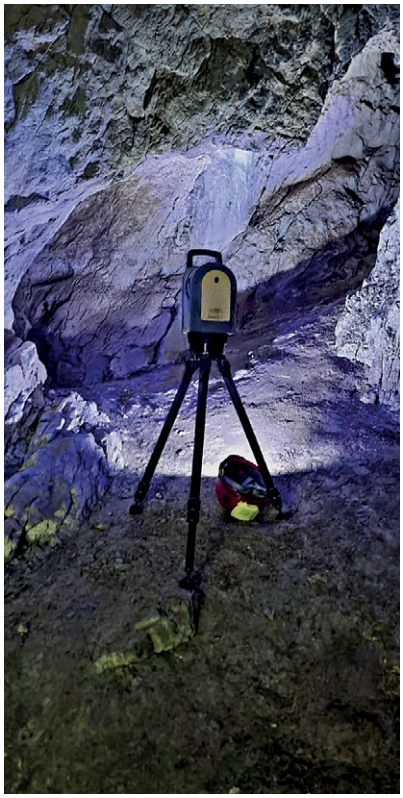

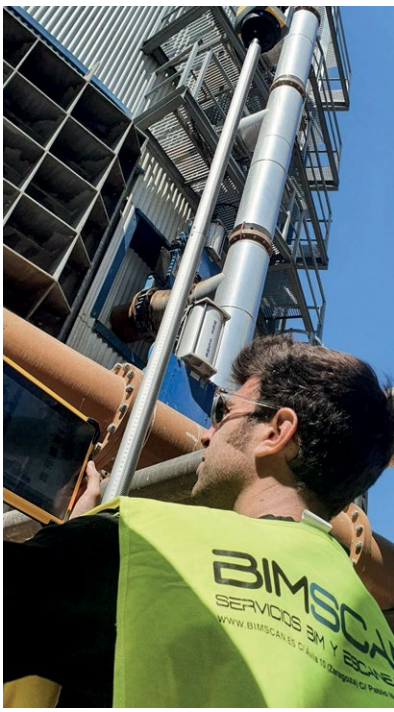

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