LIDAR

MARCH/APRIL 2020

MAGAZINE

COASTAL MAPPING

LIDAR
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◀ **ON THE COVER**
Lituya Bay, Alaska was among several locations mapped as part of a JALBTCX initiative in July 2019.

QUICK-FIND: Our digital edition offers searchability, hotlinks, video and more. The search-glass icon or find bar is accessible on any tablet or computer.

To Have and to Hold

This edition has much to do with the Geo Week 2020 series of conferences, originally slated for March 22-26 in Washington D.C. As this edition went to press, conference organizers were ultimately forced to postpone the events, the result of an unfortunate set of circumstances thrust upon countless leadership teams faced with curtailing the highly infectious COVID-19 virus.

The Geo Week banner was created by Diversified Communications to describe the co-location of three geospatial conferences—International LIDAR Mapping Forum 2020, ASPRS 2020 Annual Conference and MAPPS 2020 Federal Programs Conference. Nominations for the LIDAR Leaders Awards, a joint initiative of Diversified Communications and LIDAR Magazine, were accepted for the third time: once again, we received a bevy of high-quality submissions and the Advisory Committee agonized at length over its selections. There is a preview of finalists on page 6. Also previewed are the ILMF keynotes, talks that invariably set the tone for each year's forum.

This year, Geo Week was transitioned to Washington, D.C., a change from the usual Denver venue and an opportunity for the event to grow. Early indications were that this was indeed happening: registrations at various milestones were ahead of those last year. At the time of this writing, the COVID-19 virus was wreaking havoc across the globe, casting a shadow over any event arranged to bring far-flung peoples together. Meetings large and small have been postponed or outright canceled, while others have been beset by travel restrictions imposed by employers or local governments—all in attempt to contain the virus. In the words of motivational guru Denis Waitley, we should "expect the best, plan for the worst and prepare to be surprised".

As we pine for happier times, let us enjoy the content in this issue. I always like to find a context for each issue's articles, exploring how they exemplify excellence or trends in the industry, the profession and the technology, not dissimilar to what Geo Week represents!

We lead with a piece by Jennifer M. Wozencraft of Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX—your editor struggled to pronounce this during the 2019 Lidar Leader Awards presentation) about a coastal project in Alaska in which some of the work was done by Woolpert. Following that, we have a piece about Ron Chapple, whose GEO1 company operates out of Hawthorne airport, not far south of LAX, and acquires still and video imagery as well as lidar for clients across the globe. Ron's work over the past 20 years spans a remarkable series of projects, including novel archaeological work, and, more recently, dispatches

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TrueView
Planning and conducting drone LIDAR missions as well as the best practices in post-processing of collected data from drone LIDAR.

LP360
LP360 topics will include: Accuracy Assessment, QC tools, breakline addition/enforcement and special topics.

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Arttu Sonninen, will be providing in-depth training on new features in Terrasolid for both airborne/drone and mobile laser scanning.

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to Hawai'i, Mount Everest, the jungles of Colombia, and the urban environment of Hong Kong.

Amongst all this, you'll find a range of company listings, many of which were contributed by companies that planned to exhibit during Geo Week. We offer these in attempt to "set the stage", familiarizing you with firms that are driving our industry forward.

Last but not least, you'll find an interview based upon a visit I made to Applanix, the Canadian GNSS/IMU wizard which was acquired by Trimble in 2003. I didn't have to do much—the piece is an interview of Joe Hutton, director for airborne products. Joe spoke, I recorded, and we learned in depth not just about Applanix as a company but about the evolution of GNSS/IMU technology and the trend towards UAV applications of both photogrammetry and lidar. Sometimes it's best to relax, let the expert speak, and absorb the wisdom!

I've written in previous editorials about the useful insights we sometimes gain from sources outside the geospatial mainstream. Recently, I enjoyed a piece in *Photonics Spectra* about automotive lidar[1]. In *LIDAR Magazine*, we often publish articles on companies whose primary markets are automotive, i.e. autonomous vehicles and advanced driver-assistance systems, and we have updates in the pipeline on Quanergy Systems, Cepton Technologies, Velodyne LiDAR and Intel. Owing to fortuitous parallels between automotive and UAV applications, these companies' products have made an indelible mark on the geospatial landscape, for

example mapping and smart cities, since their price points reflect both the requirements and the depth of the R&D pockets of the car industry. Smolka's article gives some background that helps us understand the synergies. He notes that there was approximately $1.2b venture capital investment in lidar in the first nine months of 2019. He characterizes trends and it's an intriguing exercise to surmise how these could affect those of us in the geospatial world.

Lastly, I want to mention a couple of things I've read, concerning mapping in one form or another, but not closely related to our lidar world. At the end of an essay on particle physics, *The Economist* quoted Jon Butterworth, a member of the team that discovered the Higgs boson in 2012: "My whole career there's been a very clear road map of what we need to do next and now there isn't one. We've outgrown our road map. Experiment is ahead of the theory. It's an interesting and difficult time."[2] It's tough being a particle physicist these days. Is there a lesson for the geospatial leadership? The second is another of those delightful coincidences we encounter in the geospatial world. I wrote on our digital site about moderating a session on smallsats at the recent GeoBuiz Summit in Monterey[3]. One of the panelists represented the Canadian company GHGSat, which specializes in detection from space of emissions such as methane. One of its satellites detected a plume of methane apparently from a gas pipeline in

Turkmenistan[4]. Further observations through the year suggested the leak had been fixed. There's a lot more to the story, but it's a privilege to have been on the same platform as a company so clearly on the leading edge. Long may it continue.

Let's end by returning to the mainstream: airborne lidar from manned aircraft. I scribbled a few words for the magazine's digital site about my recent visit to the 2020 Los Angeles Geospatial Summit, held at the University of Southern California on 28 February[5], and expressed my delight at receiving a copy of the beautiful Esri book *GIS for Science*. This immediately became bedtime reading, even before I could finish Isaacson's tome on Steve Jobs (I picked this up second-hand for $1—who wouldn't?). It didn't take long to come across a superb essay on landslides and other natural hazards in the state of Washington[6]. Lidar is the underlying technology, the data is available on the Washington Lidar Portal and extensive further resources are provided by Esri[7]. The company's vast marketing reach will ensure that lidar's contribution reaches the desks of scientists across the globe. Have a look!

A. Stewart Walker // Managing Editor

1 Smolka, G., 2020. Market trends in automotive lidar, *Photonics Spectra*, 54(1): 56-61.

2 Anon, 2020. Physics: assembling the future, *The Economist*, 434(9175): 57-59, 4 January.

3 https://lidarmag.com/2020/01/28/2020-starting-at-the-top/

4 Anon, 2020. Climate change: the methane hunters, *The Economist*, 434(9179): 69-70, 1 February.

5 https://lidarmag.com/2020/03/11/los-angeles-geospatial-summit/

6 Coe, D., 2019. What lies beneath, Wright, D.J. and C. Harder (eds.), *GIS for Science: Applying Mapping and Spatial Analytics*, Esri Press, Redlands, California, 237 pp: 22-41.

7 www.GISforScience.com.

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LIDAR**LEADERS**

For the third year in a row, 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.

Five categories were offered this year:

Outstanding Personal Achievement in Lidar

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

Outstanding Enterprise Achievement in Lidar *(groups of 100+)*

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 this year's finalists:

Personal Achievement in Lidar

C. Wayne Wright, NOAA, USGS
Wayne Wright has a long and distinguished history in advancing airborne lidar research. After working with NASA, Wayne moved to USGS and developed the specialized Experimental Advanced Airborne Lidar (EAARL) focusing on issues unique to coastal land surface and bathymetric mapping.

Karen Schuckman, Penn State
Karen Schuckman has made numerous contributions and has sustained forward thinking leadership in advancing the mainstreaming of lidar technologies in the geospatial/ mapping community. Over the 12 years she has been at Penn State, Karen has personally taught over 1,000 students.

Team Achievement in Lidar (2-99 members)

Blue Marble Geographics
Blue Marble Geographics has been a pioneer in the development of powerful and innovative geospatial software for nearly three decades. Blue Marble's Global Mapper LiDAR Module provides users with numerous lidar processing tools, such as 3D model or mesh creation, automatic classification, feature extraction and more.

The Melbourne Arts Precinct Realm
The Melbourne Arts Precinct Realm (MAPR) Project is a bold proposal focused on the enhancement & expansion of creative spaces in Melbourne's Southbank. Development Victoria engaged Taylors to deliver an innovative digital spatial solution to assist in documentation, maintenance & redevelopment of this culturally significant area.

Outstanding Enterprise Achievement (+100 Person Enterprise)

Dewberry
Dewberry has made an outstanding impact on mapping technology over the past 20 years. The team has pioneered America's use of lidar, which is now widely used by government agencies.

Livox Technology Co.
Livox has made a name for itself by providing sensors at significantly lower costs. With its MID-40, a $599 3D lidar sensor, Livox brings affordable lidar technology to market.

Outstanding Commercial Innovation

GeoCue's True View 410 System
There are several companies providing sensor and workflow technology for the small Unmanned Aerial Systems market. However, few offer an integrated end-to-end solution forcing users of sUAS sensors to piecemeal systems together. GeoCue's TrueView solution addresses these problems. The True View 410 is available under a unique Hardware as a Service (HaaS) subscription model.

ASTRALite Edge Topo-Bathy Lidar System
ASTRALiTe's scanning lidar capability can be used for both small scale and larger scale survey and mapping projects of streams, rivers, ponds, lakes, and coastal environments. This advancement has proven applications in underwater infrastructure inspection, military logistics, natural disaster assessment and recovery, water engineering and water resource management.

BY DR. MICHAEL **ZANETTI**

The Role for Lidar in Lunar Exploration and Beyond

NASA is returning to the Moon with the Artemis Program. By 2024, NASA has been directed to land the first woman and the next man on the lunar surface, and with this, begin the groundwork for a sustained presence on the Moon that will allow us to venture on and land humans on Mars. This will be done through the development of innovative technologies, and in collaboration with commercial and international partners. This is not fantasy, we have started, this our mission, and we are going.

With the Artemis program (named after the Greek goddess of the Moon, and twin sister of Apollo), we are now returning with a substantially different and more complicated mission. Between 1969 and 1972, Apollo landed 6 missions and 12 men on the Moon. These explorers were never stationed more than 3 days, and collectively spent a mere 82 hours walking on the lunar surface. With this limited experience, how can we sustain a long term existence (i.e. weeks or months) on another planet? In order to explore further into our Solar System and land humans on Mars, we need to know how to live and operate for long durations. The Moon provides an exceptional place for us to test and practice our capability to survive and thrive in exceptionally harsh conditions, and provides us with resources that can be used to sustain ourselves.

The target landing sites for the Artemis program are at the Lunar South Pole.

There, the Sun's light barely raises above the horizon, creating areas of permanent shadow that exist directly adjacent to areas of perpetual sunlight. Trapped in the shadows are traces of water ice in quantities large enough to allow extraction of water for drinking, oxygen for breathing, and hydrogen for rocket fuel. (H_2O is a wonderful thing, isn't it?…). Perpetually sunlit "Eternal Peaks of Light," experience as little as 5 days of intermittent darkness per *year*, and provide a near limitless and readily available source of power for a sustained presence. Despite the benefits afforded by these shadowed and sunlit conditions, they present major challenges for operating on the lunar surface. The sun will sit directly on the horizon, never rising more than 3° above the surface. Down-Sun (i.e. the sun behind observer, 0° phase), there is no shadow detail and the scene is washed out. Up-Sun, the conditions will be blinding, and potentially hazardous for instruments (or Astronauts) that look in its direction. In between, the Sun will cast long shadows behind even small boulders, obscuring obstacles or exaggerating the appearance of slopes.

But it is in these conditions that exists the role for lidar. As an active source instrument, lidar can see into these shadows, mapping the topography and surveying the landscapes in ways that traditional photogrammetry based vision systems would struggle. lidar sensors, particularly those like

frequency modulated continuous wave (FMCW) sensors that are robust to solar glare interference, provide the means for accurate navigation regardless of up- or down-Sun illumination and traverse conditions. Importantly, lidar enables a 3D representation of the environment that can be made in real-time (e.g. for an Astronaut's heads-up display, and is ready-made for virtual reality immersion that will engage the public in ways never before possible. Lidar presents its own challenges, for example in terms of data volumes, operating temperatures, power consumption, and space-environment technology readiness levels, but the development of a space system has clear benefits that could get translated into defense and commercial applications. I'm confident that lidar will become an integral part of the future of planetary exploration in the Artemis program and beyond. ∎

Dr. Michael Zanetti, NASA Marshall Space Flight Center, National Space Science & Technology Center, Huntsville, AL

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BY TARA **O'SHEA**

Finding the Value in Our Forests

We're racking up a huge ecological debt due to mass deforestation. The Earth is losing rainforests at a rate of 30 football fields per minute, and they're being converted into more "economically productive" resources for things like mining or industrial agriculture. This has turned the world's largest terrestrial carbon sink into our second largest source of climate-changing greenhouse gas emissions.

A lot of this is happening because we're not properly valuing our forests—because historically, we haven't had the tools to measure their impact. And when it comes to creating better forest management practices, you can't fix what you can't see.

But remote sensing technologies can help change the landscape of our forests' future.

Lidar sensors enable us to directly measure forest carbon and thereby better understand the value of a given forest at a point in time. We now have the ability to combine lidar imaging with parallel advances in spaceborne remote sensing and machine learning to expand this valuation over time. With these technological advances, it's becoming possible to practically and cost-effectively measure the services forests provide in a spatially-explicit and global way, at high-frequency.

These are exactly the sorts of applications we're seeing across a number of partners and customers at Planet, the leading provider of global, near-daily satellite imagery data and insights. Planet offers tools and information that can help humanity make informed, timely decisions and solve our world's toughest challenges. In my role as Planet's director of forest programs, I've had the opportunity to see our customers and partners building models trained with lidar and powered by Planet data. Arizona State University, SaloAI and Pachama are organizations making it easier than ever to account for the services forests provide in economic and policy decisions, leading to better outcomes for climate change mitigation, biodiversity conservation and wildfire preparation.

Remote sensing technology is one of our best tools to help build a better, greener world, and I know this because I've dedicated myself to forest preservation for the last 12 years.

Over a decade ago, I was working with development aid projects in a rural village in northern Nicaragua. The region was economically dependent on coffee farming; smallholders supplied multinational commodities corporations with coffee beans. Livelihoods depended on the health of fields and crops, which in turn relied on the health of local watersheds.

But the health of local watersheds was rapidly deteriorating. The most affordable source of household energy was firewood sourced from local forests, and the economic incentive to deforest surrounding hills was killing the economic production of the valleys. Economic incentives were actually *hurting* my community's prospects for economic development.

Since then, I've worked with this community in mind to figure out how to change these perverse incentives, to better align natural and economic systems to create more sustainable pathways to economic development. Time and time again, I've come back to the realization that you can't fix what you can't see. Remote sensing and analytics technologies empower us to take action.

We need to create a world where forests are a valued use of land, where communities have more choice than racking up ecological debts in order to receive short-term high-interest loans. The combination of remote sensing and analytics technologies can help us get there.

Tara O'Shea is the director of forest programs at Planet.

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Addressing Dire Coastal Mapping Needs on The Last Frontier

JALBTCX team acquires data critical to Alaska communities

BY JENNIFER M. **WOZENCRAFT**
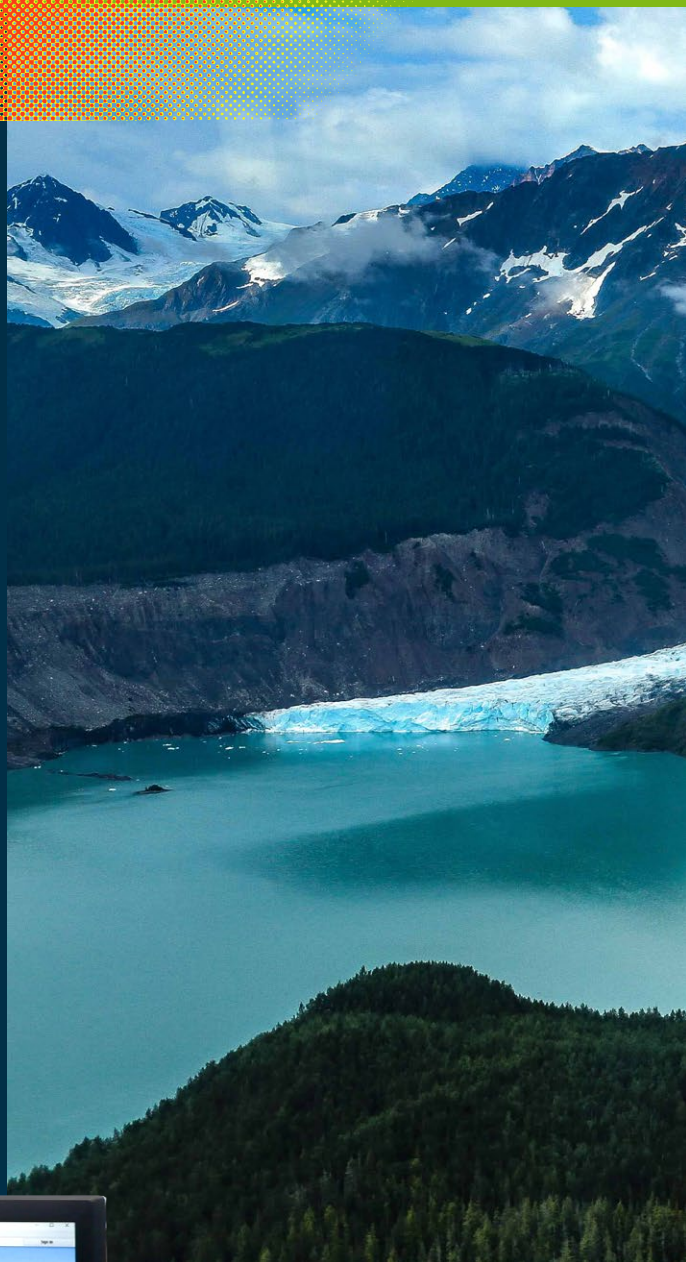
The U.S. has more than 95,000 miles of coastline[1], and its effective management is vital to the economy, environment and safety of the nation. The coastline defines our maritime boundaries, is home to 40% of the nation's population, and accounts for $8.3 trillion in goods and services annually.

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1   https://coast.noaa.gov/states/fast-facts/ economics-and-demographics.html

USACE Mobile Scientist Chris Macon works with lidar data collected over Alaska.
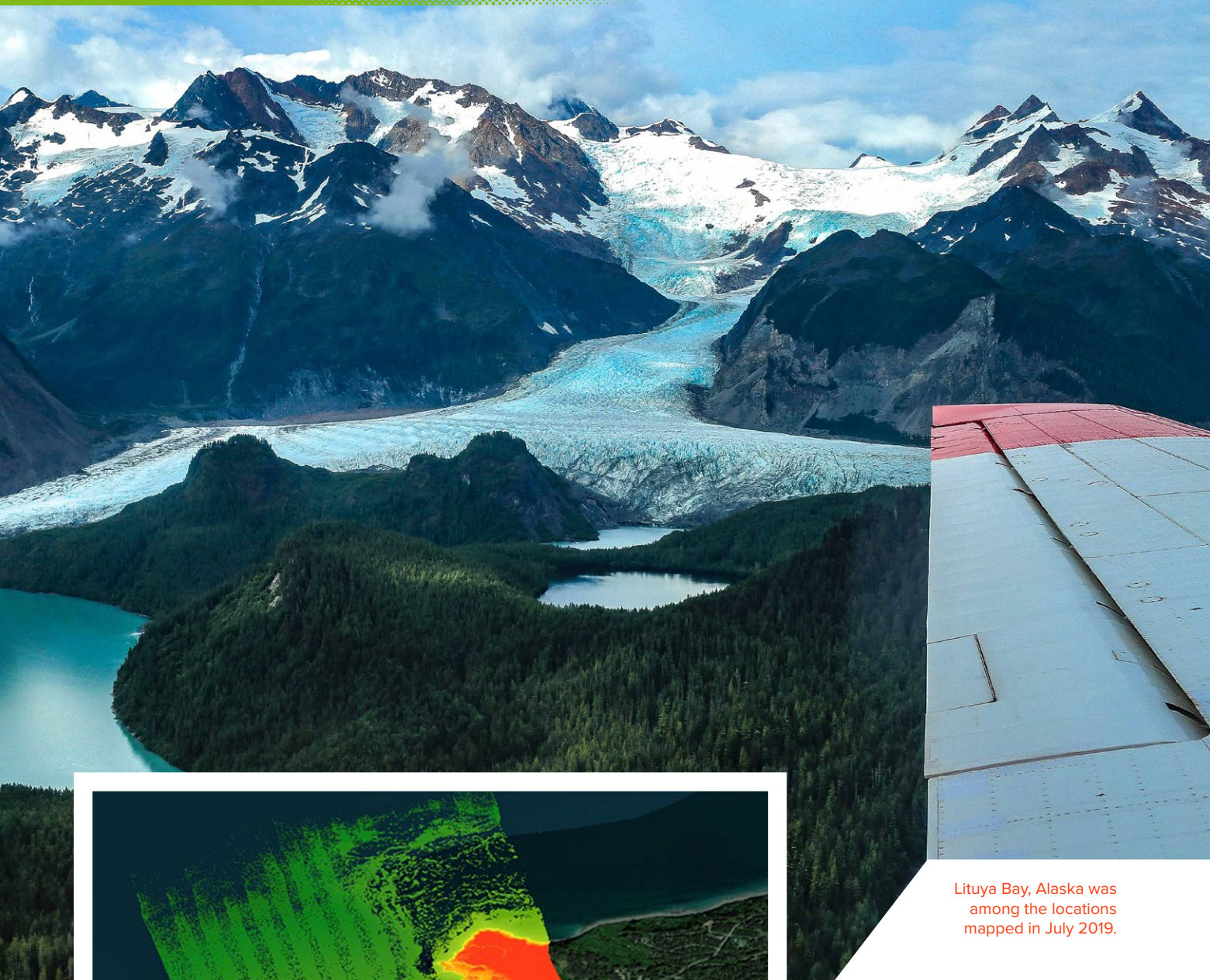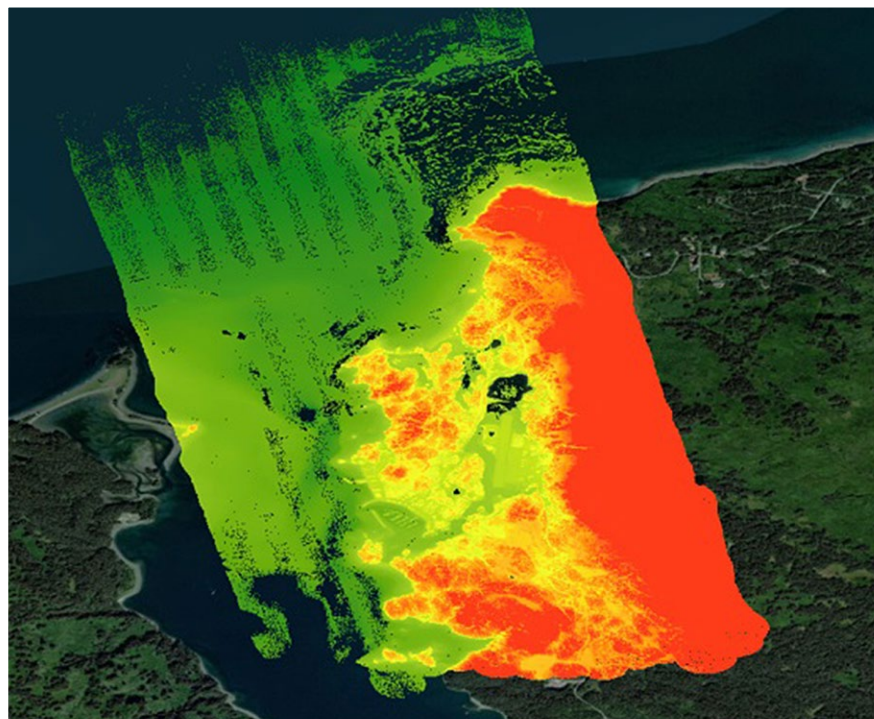
Seldovia, Alaska, is seen via lidar data.

And—because of natural, constant and sometimes extreme change—it is a moving target.

In Alaska, which comprises more than twice the coastline of any other state[2], the need for coastal data is amplified. In addition to large-scale environmental hazards like storm surge, earthquakes, volcanoes and tsunamis, the Alaska Division of Geological & Geophysical Surveys (DGGS) reports that 87% of all

2 https://coast.noaa.gov/data/docs/states/shorelines.pdf

This view of the Homer Spit was taken during the USACE lidar collection.

Alaska Native communities experience flooding damage and coastal erosion[3]. These natural processes destroy infrastructure, threaten personal safety and livelihoods, and increase the financial burden on state and local economies.

Even though strides have been made to survey and map Alaska[4], there are many needs for baseline coastal geospatial data to effectively evaluate and monitor Alaska's coastal regions. Alaska coastal mapping data would address data gaps that are critical to the safety of navigation, infrastructure planning, storm-surge modeling, tsunami modeling, regional erosion monitoring and emergency response.

The Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) provides airborne lidar bathymetry and complementary technologies to support the coastal mapping and charting requirements of the U.S. Army Corps of Engineers (USACE) in support of the National Coastal Mapping Program (NCMP). The NCMP's stated goals are to develop regional, repetitive, high-resolution, high-accuracy elevation and

imagery data; build an understanding of how the coastal zone is changing; and facilitate the management of sediment and projects at a regional, or watershed, scale.

JALBTCX owns and operates the Coastal Zone Mapping and Imaging Lidar (CZMIL) systems year-round and worldwide in support of the USACE and the Naval Oceanographic Office (NAVOCEANO), collecting

high-resolution lidar bathymetry and lidar topography elevation data, as well as hyperspectral and true-color aerial imagery. Each summer, one of these systems transits through Alaska on its way back from supporting NAVOCEANO operations in the Pacific.

JALBTCX took full advantage of the opportunity to employ high-tech survey equipment already being utilized in Alaska

The Kenn Borek Air Balser BT-67, equipped with a Coastal Zone Mapping and Imaging Lidar system sensor, was used to collect data over Homer, Alaska. USACE personnel evaluated which sites and stakeholders would yield the greatest impact from a data use perspective, and which were likely to be operationally feasible given terrain and water clarity conditions in Alaska. Homer, a coastal town on the southern edge of the Kenai Peninsula, was identified as the first pilot area.

3   http://dggs.alaska.gov/webpubs/dggs/ic/text/ic068.pdf
4   https://dggs.alaska.gov/hazards/coastal/baseline-data.html

to collect high-resolution bathymetric and topographic lidar data in Homer in 2018 and at multiple locations throughout the state in 2019. Since mobilizing airborne surveying and mapping equipment is expensive, leveraging this opportunity with normal operations allowed JALBTCX to cost-effectively characterize the capability of a deep-water bathymetric lidar system in new, challenging mapping environments, and to better understand logistical challenges of airborne bathymetric lidar operations in Alaska.

By coordinating these collections with federal and state partners that included the USACE Alaska District, DGGS, the U.S. Geological Survey (USGS) and the National Park Service, JALBTCX provided essential high-resolution elevation data of the coastline to effectively address the need for data to support coastal engineering, coastal storm surge modeling and tsunami modeling for communities in Alaska. Woolpert and Optimal GEO supported the USACE project through the firms' joint venture, WMR-532.

"Alaska communities are all closely tied to the water—whether participating in sport, commercial or subsistence

The Homer Spit is 4.5 miles long and juts out into Kachemak Bay. The dynamic landmass is challenged by accretion and erosion due to regularly occurring storms and seasonal tides.

fishing; for transportation; or for receiving goods where roads don't reach. Due to the proximity of communities to coastal waters and the reliance on coastal ecosystems, Alaska needs a

seamless nearshore dataset that goes from land to water," said Jacquelyn Overbeck, who manages the DGGS Coastal Hazards Program. "Lidar generates the kind of high-resolution dataset that meets Alaska's critical shoreline mapping needs. The recent work by JALBTCX in Alaska has provided shoreline data in areas that have never been collected with topographic-bathymetric lidar, so this data is fulfilling a need that has yet to be met in the state."

Developing a strategic plan

Marta Kumle, Alaska coastal mapping strategist, is leading the development of the Alaska Coastal Mapping Strategic Plan. An assessment was conducted to determine the data needs of state, regional, federal, academic, professional and nonprofit organizations. The data
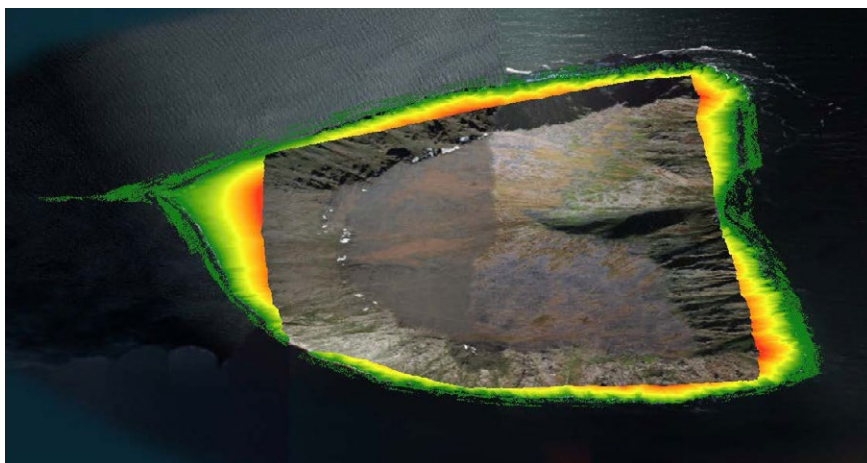
Little Diomede Island, Alaska was mapped by the USACE crew in 2019.
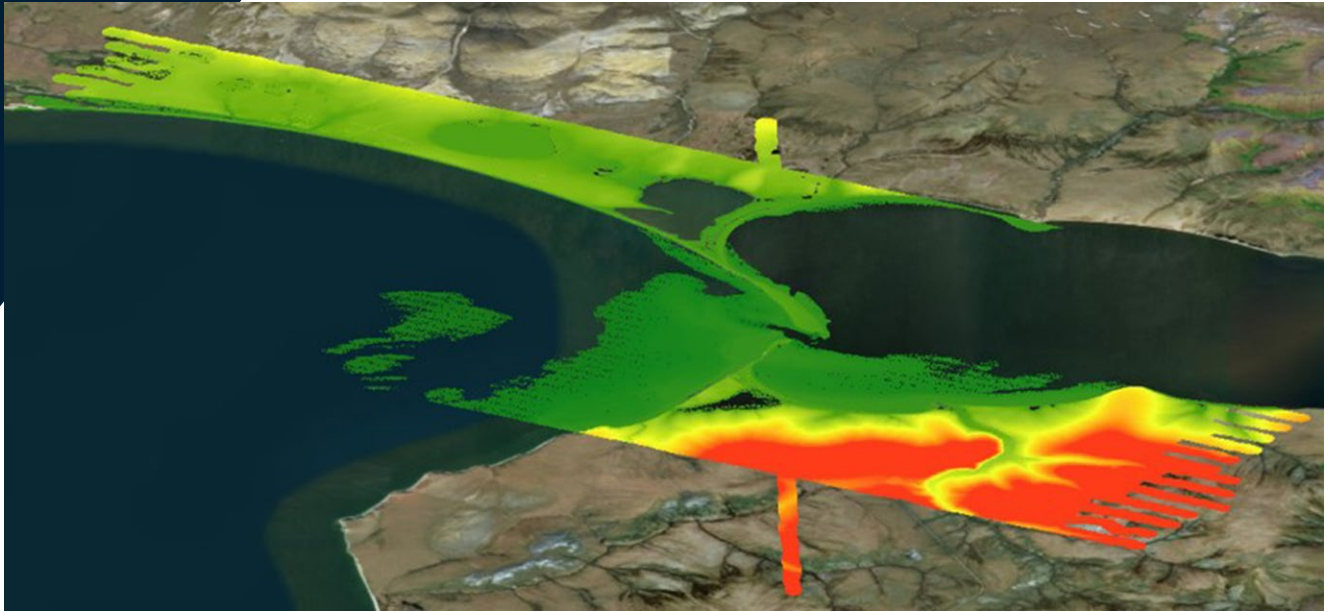
Lidar data of Port Clarence, Alaska.

needs support a wide range of applications, such as engineering and hazard mitigation, land management, national resource management, emergency response, vessel navigation and general knowledge for miscellaneous applications.

A grading system was created to evaluate the quality of existing public elevation data that included bathymetry, topography, orthoimagery and shoreline vector data. The data was then integrated with information from a stakeholder survey to develop spatial prioritization to support a five-year strategic plan for data acquisition. To grade the existing continuous and overlapping topographic-bathymetric datasets, an algorithm was applied that factored in the age of the dataset, its resolution and the quality of the technology used to collect it.

"The plan aims to strategize data acquisition in our state to meet as many stakeholders' needs as possible, so data can be used for many times for different

purposes," said Kumle. "Drawing on the grading system and survey results, the strategic plan will be a roadmap to meet requirements and mapping priorities for the longest state shoreline in the United States."

John Gerhard, Woolpert vice president and director of maritime solutions, said that the goals of developing a strategic coastal mapping plan in Alaska include assisting the state in defining and assembling coastal mapping priorities, encourage collaboration in data collection, and attracting state, federal and partner funding to invest in the coastal mapping requirements.

"Alaska has more than 280 coastal, riverine or lakeside communities spread across its vast geography that are not connected by roads," Gerhard said. "Shorelines are rapidly changing due to erosion, storm surges are flooding communities and displacing populations, and the stability of existing infrastructure is at risk. Accurate, high-resolution geospatial

data is essential to prioritize and address Alaska's coastal mapping requirements."

Mapping in Alaska

To begin its mapping project, USACE personnel evaluated which sites and stakeholders would yield the greatest impact from a data-use perspective, and which were likely to be operationally feasible given terrain and water clarity conditions. Homer, a coastal town on the southern edge of the Kenai Peninsula, was identified as the first pilot project area.

Multiple geologic hazards such as coastal flooding, tsunamis, earthquakes and slope instability impact Homer's nearly 5400 residents, many of whom have homes on high-elevation coastal bluffs. The city's most notable feature is the Homer Spit, a 4.5-mile long, narrow finger of land that juts out into Kachemak Bay. The Spit is a dynamic landmass that is challenged by accretion and erosion due to regularly occurring storms and seasonal tides.

Enhanced elevation datasets have been sought to address and improve hazard modeling, provide technical assistance for the city to develop a setback policy for building near coastal bluffs and aid the City of Homer Port and Harbor, which supports a diverse commercial fishing fleet and thriving marine industrial and maritime transportation industries.

"This data being collected will be very valuable for us as we expand the harbor systems and create a large-vessel harbor, which we've been planning for years," Homer port director/ harbormaster Bryan Hawkins said. "It will help mitigate navigational hazards and will help us work with the USACE to develop a dredged materials guidance plan for the Homer Spit."

For the Homer mission, the JALBTCX survey crew had planned 12 flight hours over three days in June 2018. That quickly evolved into 14 hours to accommodate local tidal conditions within Alaska's already narrow collection window, rugged terrain and dense canopies of kelp fields. "The coastline of Alaska has many differing conditions, creating data collection and processing challenges," said Mark Brooks, Optimal GEO chief operating officer. "The team's ability to identify these challenges and to quickly modify the survey plan allowed us to produce a successful project." The 14 flight hours successfully produced 47 flight lines over the 25.5 miles of Homer's beach and shallow water seafloor, reaching a maximum depth of 21.4 m and yielding 406 million valid topographic and bathymetric measurements.

In July 2019, the crew returned to Alaska to conduct additional survey operations at multiple locations in acute need of data by federal and state
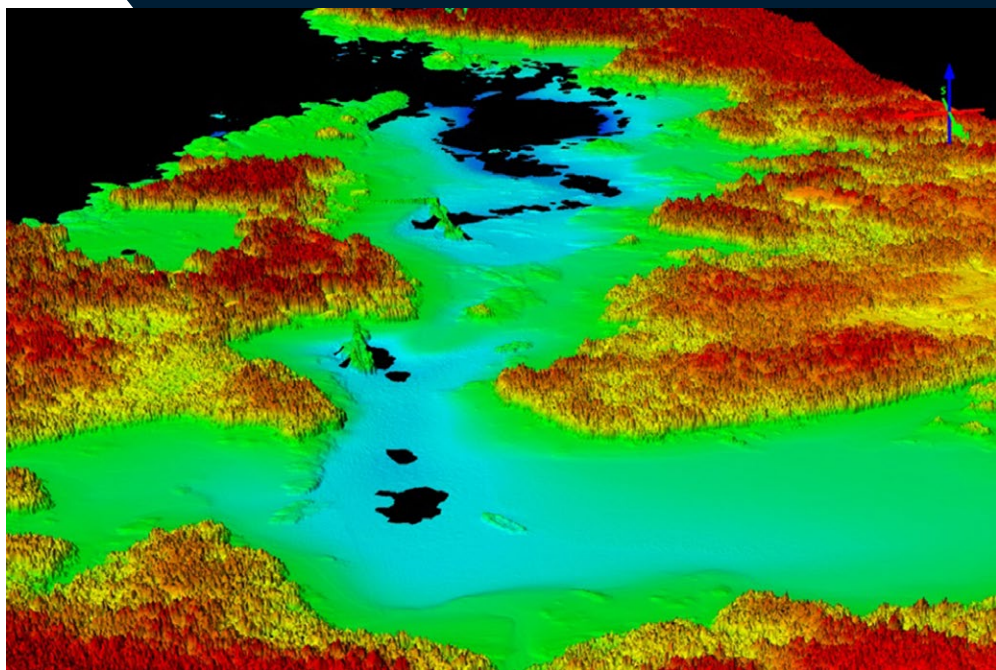
Lidar data illustrates Port Alexander, Alaska.

partners for multiple applications. Sites were selected by the USACE Alaska District based on feasibility of airborne operations and probability of success of bathymetric lidar to fulfill the seamless topo-bathy mapping data needs. Airborne bathymetric lidars typically operate at 400 m altitude and require relatively clear water for depth measurements. The rule of thumb for deep-water bathymetric lidars like CZMIL is depth measurement from two to three times the Secchi depth, or visible depth of the water. Between July 9 and July 27, the flight crew flew 18 missions for 13 priority areas, collecting 416 square miles of topographic and bathymetric lidar data. Mapped locations include Little Diomede Island, Golovin, Port Clarence, Point Hope, Seldovia, Unalakleet, Voznesenka, and the Gulf of Alaska from Lituya Bay to Palma Bay.

"The Alaska Coastal Mapping Strategic Plan and the communities

most affected by coastal hazards were considered when coastal storm surge and tsunami modeling priorities were selected for the 2019 survey operations," Overbeck said. "With the assistance of JALBTCX, we have several enhanced elevation datasets that help meet the goals of a comprehensive and coordi-nated plan to map Alaska's coast."

The flight crew was based at three airports during the flight operations: Anchorage, Juneau and Nome. The crew logged 102 flight hours, 53 online survey hours and 39 transit hours. The transit hours included flight time between the survey locations from these airport bases, as well as the additional flight time incurred when inclement weather diverted the aircraft to another airport. The trajectory information and data cov-erage were reviewed daily by deployed USACE Operations and Woolpert staff at a field office in Anchorage, and the

Crews accommodated local tidal conditions within Alaska's already narrow collection window, and the consistent threat of inclement weather.

final data products were produced at the JALBTCX Stennis office by USACE and Optimal GEO staff. The final data products included the classified point cloud in LAS format, digital surface models, digital terrain models, RGB imagery at a 5 cm pixel resolution and 48-band hyperspectral imagery at a 1 m pixel. Additional products generated at the request of local stakeholders included a subaquatic vegetation classification, yielding additional biome and environmental applications.

Challenging aspects of these projects included complex, turbid and temporally dynamic shallow deltas in the Golovin area, as well as rocks located in many areas of the littoral interface. This complicated light absorption and multipathing inputs during the data validation process.

Map once, use many times

The Alaska Coastal Mapping Strategy and supporting JALBTCX surveys in Alaska exemplify the concept of "map once, use many times," promulgated by the U.S. Interagency Working Group on Ocean and Coastal Mapping[5]. With coordination among as many

stakeholders as possible early in the survey planning process, a single data collection can meet the data requirements of many data users and a broad range of applications.

Woolpert program director Mark Smits said that these types of projects support Alaska's coastal mapping needs by improving the quality and quantity of the critical baseline data of shoreline conditions in Alaska, and

they support the needs of people and programs around the world. "Due to its high resolution and fidelity, this data can be used across countless domains by multiple agencies and for multiple applications—providing each with timely and accurate information," Smits said. "Lidar bathymetry and topography are not only employed by the USACE, NAVOCEANO and others around the world, but they enable the DGGS to coordinate its goals with programs like the NCMP to benefit both. To have accomplished this collection efficiently and within a challenging environment such as Alaska is a win for all involved." ■

Jennifer M. Wozencraft is the U.S. Army Corps of Engineers National Coastal Mapping Program Manager and Director, Joint Airborne Lidar Bathymetry Technical Center of Expertise

All images and data are courtesy of the USACE National Coastal Mapping Program.
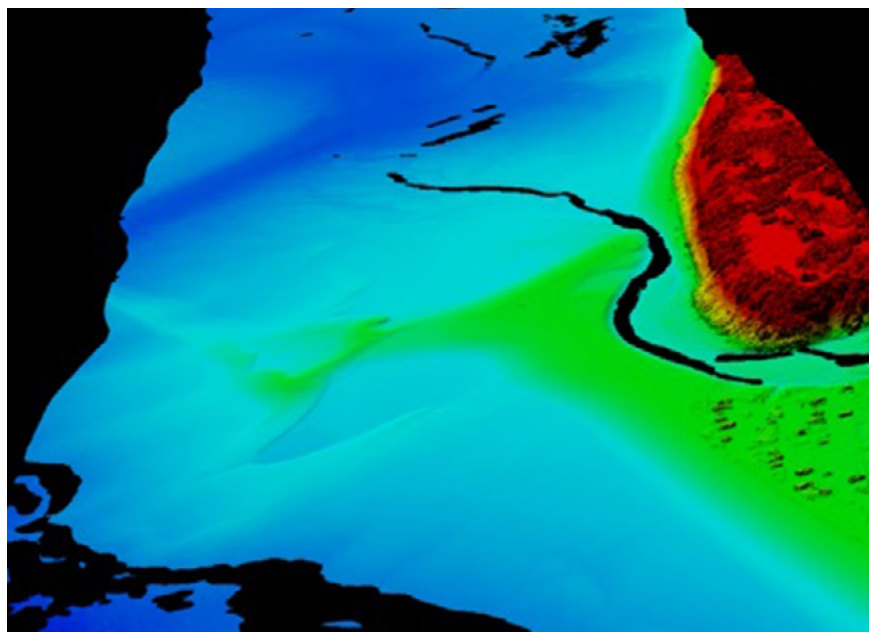
Ninilchik, Alaska, is seen via lidar data.

5   https://iocm.noaa.gov/standards.html

Dewberry

Dewberry is a leading, market-facing firm with a proven history of providing professional services to a wide variety of public- and private-sector clients. Recognized for combining unsurpassed commitment to client service with deep subject matter expertise, Dewberry is dedicated to solving clients' most complex challenges and transforming their communities. Established in 1956, Dewberry is headquartered in Fairfax, Virginia, and has more than 50 locations and 2,000+ professionals nationwide.
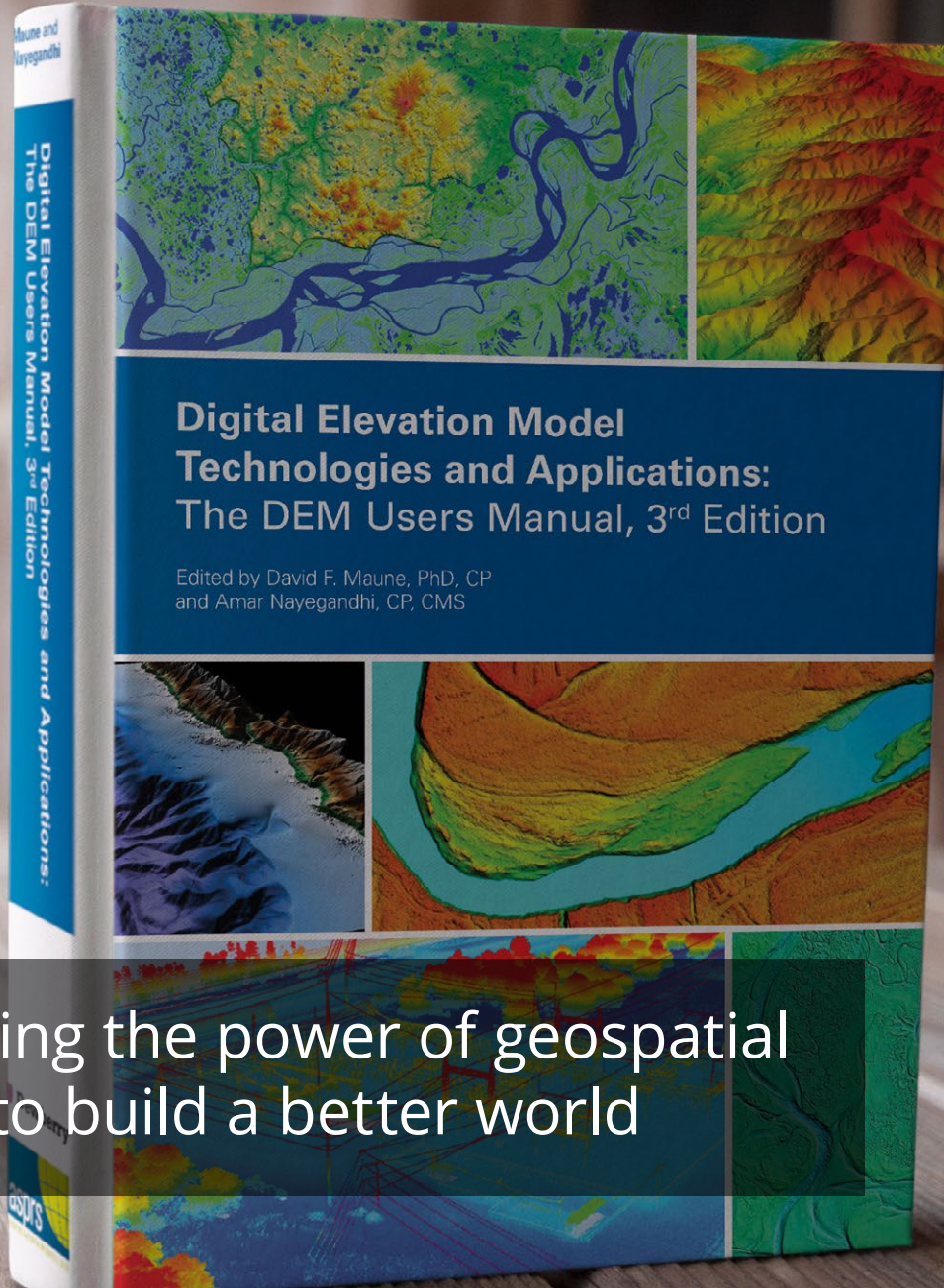
With comprehensive geospatial products and services, we help clients deliver mission success. We're a privately held, family-owned, full-service engineering firm committed to helping federal, state and local, and commercial clients serve communities nationwide. Our consulting team includes many of the most recognized and respected industry experts and thought leaders. We create, analyze, and build tools to share geospatial data, as well as help clients integrate these tools into their daily lives. We fuse multiple data sets together and provide clients with easy-to-use tools that simplify the use of information to allow for more effective and efficient decision making.

Our firm wrote the book on lidar—The *DEM Users Manual* 3rd Edition—which includes lidar standards, guidelines, and specifications for the 3D Elevation Program (3DEP). We developed lidar quality levels, widely used today, and authored the National Enhanced Elevation Assessment, which provides the blueprint for the 3DEP based on QL2 lidar or better for all states except Alaska. For Alaska, we were selected by USGS to acquire, process, and quality control airborne IFSAR data to meet QL5 specifications. Additionally, we authored the Florida Statewide Lidar Assessment that established higher-resolution QL1 topographic lidar and QL0B bathymetric lidar as the state's standards. Currently, we are acquiring and producing statewide QL1 lidar for Florida, except for Leon County, where we acquired QL0 lidar with RMSEz of 5-cm. We also specialize in topobathymetric lidar and the merger of topographic and bathymetric datasets as we did for USGS and NOAA in Puerto Rico and the California coastline.
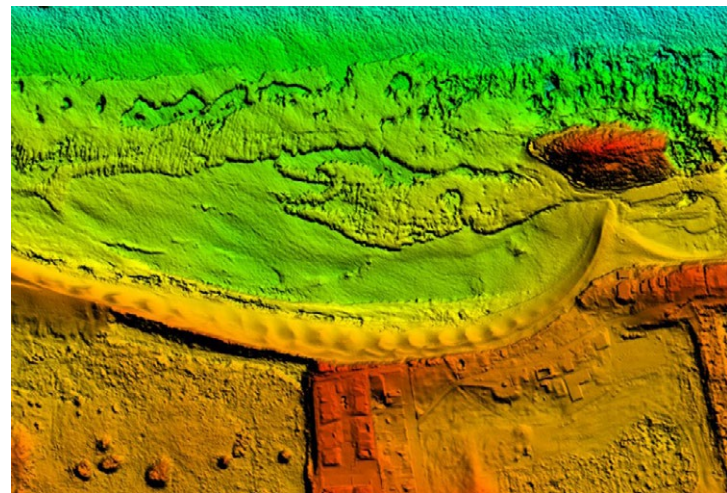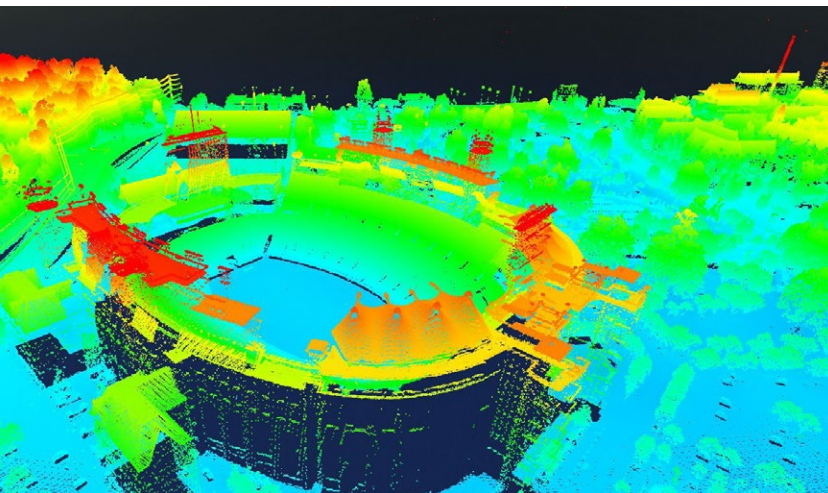
Our national team of experts provide a variety of expertise across numerous services, including remote sensing data acquisition and processing, data analytics, digital orthophotography, emergency response, geospatial benefit-cost analysis, geographic information systems, hydrographic mapping, independent QA/QC, photogrammetric mapping, raster and vector products, survey and control, technology evaluations, and topographic mapping. We employ the latest GIS software and database platforms, including the full suite of Esri products and various open-source platforms. Our products and services include application, web, and cloud-based development; system integration; database design mapping; data fusion; and mobile solutions. Not owning or operating our own aerial sensors allows us to objectively review project specifications and outline sensor types that best fit specific project needs. Our flexibility with acquisition enables us to add subcontractors at the request of our clients or work jointly with other contractors responsible for data acquisition. Additionally, we can augment clients' staff by performing independent QA/QC of data provided by other contractors. We are dedicated to our clients and believe that flexibility and responsiveness leads to optimal solutions to their toughest challenges.

Dewberry®

Amar Nayegandhi
813.421.8642
anayegandhi@dewberry.com

Dewberry®

Digital Elevation Model Technologies and Applications: The DEM Users Manual, 3rd Edition

Edited by David F. Maune, PhD, CP
and Amar Nayegandhi, CP, CMS

Harnessing the power of geospatial science to build a better world

ADDRESS

iXblue

Mandli Communications trusts iXblue's Atlans A7 INS for its data collection operations

Mandli Communications, Inc. is a technological leader in the assembly and implementation of specialized highway data collection platforms. They excel in the integration of high resolution sensors that are used for 3D pavement evaluation and precision asset extraction from LiDAR. Geospatial accuracy is a priority in the creation of the highest quality solution for the customer. To meet that standard, Mandli has turned to iXblue's Atlans A7 Inertial Navigation Systems (INS) and it is now installed in all of their next generation data collection systems

As Mandli has pushed the envelope in the use of LiDAR for DOT asset inventory and digital terrain modeling, they found it difficult to achieve the vertical resolution needed for precision measurement in the point cloud. In search of a more consistent solution, Mandli identified iXblue's inertial technology as a better choice for their next-generation data collection vehicle, the X35. Collecting highly detailed, geolocated pavement and asset data, while simultaneously streamlining and automating processes, the X35 needed the most innovative technologies to meet the challenges of data collection projects.

iXblue's Atlans A7 is a North-seeking INS that offers highly accurate positioning in all environments, even in real-time. The A7 is a prime solution for mapping operations requiring robust data georeferencing. Resistant to GPS outage, the Atlans A7 enables continuous acquisition operations within environments lacking GPS signals (such as urban canyons, tunnels, forests, and mountainous areas) proving to be a valuable system for high accuracy data acquisition without interruption.

To assess the performance of the system, Mandli and iXblue decided to run a series of tests, with Mandli providing critical feedback for fine-tuning the system. iXblue's engineers enhanced the platform with some adjustments to the INS package that made the technology a robust fit for Mandli's unique requirements. After evaluating the Atlans A7 against the other industry standard bearers, iXblue was selected to equip Mandli's new fleet of advanced vehicles.

"Our strategy was to invest in the sensor to improve our capture and spend less time on the post-processing," explains Ray Mandli, CEO of Mandli Communications. "The Atlans brings a very high-end capability in a small and cost-effective INS package— it proved to be an obvious choice.

"When no GPS is available, iXblue's INS offers greater accuracy than prior technologies, and we are creating better raw materials for the reduction phase of our work. iXblue's customer-care culture was a big part of getting us to the best outcome. They listened to our requirements and adapted the product accordingly. They are very agile and reactive. That's a big plus. We've now been using Atlans A7 for several years and delighted by the performance, durability, and quality."

About iXblue

iXblue is a global high-tech company specializing in the design and manufacturing of advanced autonomy technologies. The group in-house expertise includes FOG-based inertial navigation systems that provide highly robust and accurate positioning in all conditions, including within GNSS-denied environments and that bring efficiency and reliability to all land and air mapping applications.

www.ixblue.com

iXblue

22 LIDAR 2020 VOL. 10 NO. 2

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.

LISTING INDEX

Microdrones

APPLICATIONS

- SURVEYING
- MAPPING
- ENGINEERING
- CONSTRUCTION
- MINING
- OIL & GAS
- AGRICULTURE
- FORESTRY

COMPANY PROFILE

Microdrones grew out of the collaboration between the German inventor of the world's first commercial quadcopter and a determined surveying payload and software developer in North America. The result is a global aerial mapping technology company that delivers complete and reliable mapping systems specifically developed for the surveying, mining, construction, oil & gas and precision agriculture industries. Microdrones Integrated Systems are industrial tools addressing specific complex mapping challenges for professional customers, relying on a fully integrated geospatial workflow that enables cutting-edge software technology from Microdrones to transform raw data collected in the field by Microdrones survey equipment into valuable high-quality survey grade data. Microdrones is widely recognized for its LiDAR technology leadership.

Microdrones has facilities in Germany, Canada, France, China and the United States, as well as a sales, support and distribution network spanning six continents.

microdrones®

Founded 2005

201-500 employees

www.microdrones.com
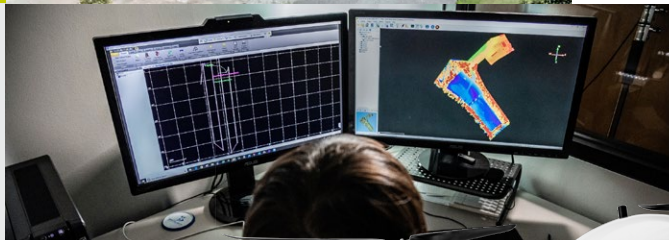
mdLiDAR3000DL

The complete package to add unmanned aerial LiDAR to your geomatics services. The mdLiDAR3000 DL uses the lifting power, resilience and efficiency of the Microdrones aircraft platform to carry a perfectly integrated Riegl miniVUX-1DL and a Sony RX1R II camera. The result? You can quickly acquire high density and accurate LiDAR data in the filed and efficiently turn it into a 3D colorized pointcloud back at the office or on your laptop.

The mdLiDAR3000DL is an end-to-end LiDAR solution combining a drone, a LiDAR payload, a fully integrated software workflow, and world class support to consistently provide quality deliverables. It's the ultimate solution to streamline your workflow, fly further, and collect more data in a full array of applications for surveying, construction, mining and more.

mdMAPPER
1000DG

mdLiDAR
1000

A MORE EFFICIENT WAY TO MAP

Crafton Tull employed both the mdLiDAR1000 and mdMapper1000DG to map a seven-mile corridor and save a customer more than 50 percent in the process.

Professionals responsible for geospatial data collection should consider mdLiDAR and mdMapper for the following tasks.

· Corridor mapping
· Mining (volume calculation)
· Construction site monitoring
· Environmental changes (time series)
· Forestry
· Contour mapping
· Leveling/Excavation
· Highway construction
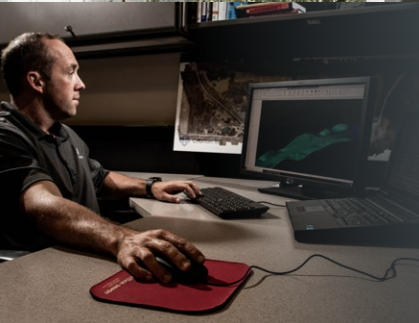
"We've worked with other UAVs in the past but what we're seeing with the Microdrones integrated system is superior. Since we've been using the mdLiDAR1000 we've gained several new customers and clients who are giving us repeat business. The investment has definitely been worth it."
—

JEFF DAVIS, UAV SURVEY COORDINATOR, CRAFTON TULL

Complete this easy online form to start a conversation with us:
lp.microdrones.com/webinar-drone-based-lidar-replay

microdrones®

RIEGL

COMPANY PROFILE

With 40 years 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. Worldwide sales, training, support, and services are delivered from RIEGL's Austrian headquarters and its offices in Vienna, Salzburg, and Styria, main offices in USA, in Japan, in China and in Australia and by a worldwide network of representatives covering Europe, North and South America, Asia, Australia, and Africa. The RIEGL headquarters provides more than 40,000 square feet work space for research, development, production, as well as for marketing, sales, training and administration. Another 350,000 square feet of open-air ground are used for product testing.

RIEGL®

Founded 1977

230+ Employees

Horn, Austria

Orlando, USA

Riegl.com

Innovation in 3D

RIEGL terrestrial laser scanners provide detailed and highly accurate 3D data rapidly and efficiently. Applications are wide ranging, including Topography, Mining, As-Built Surveying, Architecture, Archaeology, Monitoring, Civil Engineering and City Modeling.

RIEGL airborne laser scanners make use of the latest state-of-the-art laser and signal processing technology. They are exceptionally compact, lightweight and cost effective, and are designed to meet the most challenging requirements in airborne surveying.

Unmanned Laser Scanning, utilizing high-end unmanned airborne platforms, provides the possibility to acquire data from dangerous and/or hard-to-reach areas, whilst offering a high cost to benefit ratio for numerous applications, for example Agricultural and Forestry, Defense, Wide Area Mapping, Flood Zone Mapping, Topography and Mining. For years, RIEGL Laser Scanners have been successfully used in this sector. Our current efforts in R&D guarantee to provide the user with state-of-the-art laser scanning engines of the highest quality, to meeting the specific challenges of surveying applications using advanced UAS/UAV/RPAS platforms. Furthermore, we are proud to be the first major LiDAR manufacturer to develop its own unmanned aerial system.

Mobile laser scanning describes terrestrial data acquisition from moving platforms (e.g. boats, trains, road and off-road vehicles) also known as kinematic laser scanning. Both RIEGL 2D and 3D laser scanners are ideally suited for mobile mapping applications.

RIEGL's industrial laser scanner product line is ideally suited to meet demanding industrial customer expectations.

RIEGL's software packages are the ideal companion software for RIEGL laser scanners. Furthermore, smooth data transfer to numerous third party post-processing packages is a matter of fact.
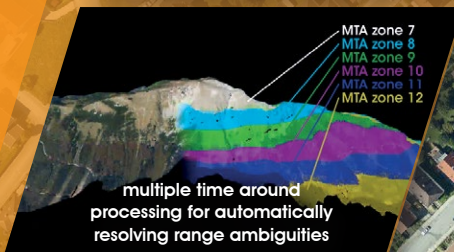
Gexcel

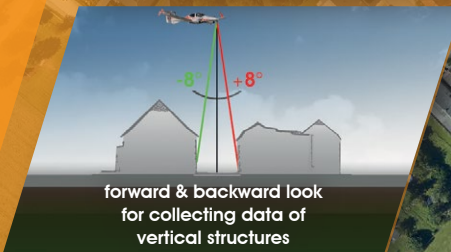## APPLICATIONS

- MAPPING
- LIDAR
- SURVEYING
- MONITORING
- CONSTRUCTION
- DEEP MINING
- TUNNELING
- INDUSTRIAL

COMPANY PROFILE

Gexcel is an Italian company with a full-proven expertise to provide innovative software and instruments dedicated to the 3D geospatial and surveying/mapping market and sold worldwide directly and by partners as ClearEdge, Faro, Geomax, Stonex, Teledyne-Optech, Zoller+Fröhlich. The first successful product, commercialized since 2001, is the well-known Reconstructor® software for laser scanner data processing. In 2016 Gexcel introduced HERON®, one of the most advanced SLAM-based wearable indoor mobile mapping system. In 2019 Gexcel presented the innovative OPMMS® (Open Pit Mine Monitoring System), easily called Monitoring System, based on automatic survey and combined with long range LiDAR scanners.

Gexcel is currently engaged in several partnerships with Universities and Research Institutes as the Laboratories of the EU Commission or the CRS4 Visual Computing (ViC).

GEXCEL
GEOMATICS & EXCELLENCE

Founded 2007

Elmas and Brescia, Italy

www.gexcel.it

HERON®

HERON® is a versatile SLAM-based system for fast mobile mapping where GNSS signal cannot be easily tracked, enriched with a real-time data visualization. The unmatched HERON® algorithm dramatically reduces the drift effects, typical of the SLAM process, generating point clouds with a geometry adaptable to any other geo-referenced point cloud of the surveyed area (obtained through UAV, MMS or TLS previous surveys), so perfectly adaptable to the existing constrains. Designed by Gexcel and the research teams of the European Commission Labs, HERON® is perfect both indoors and outdoors, and is becoming a standard for tunneling, deep mines, and cavities. Particularly appreciated also in several geospatial applications, facility management, fast mapping in large/complex areas (airports, industrial plants, forests, etc.) thanks to its 5K resolution RGB camera. The provided high-professional software guide customers from survey to final deliverables, generating results as colorized point clouds, output for CAD, and 3D data easy to share.

RECONSTRUCTOR®

Reconstructor® is a powerful full-processing software for LiDAR data from the main terrestrial, handheld, and mobile laser scanners, integrating UAV and 3D point clouds. Thanks to the LineUp® technology, Reconstructor® automatically registers 3D scans, even without targets, and the different add-ons support customers in mining, color-based and mobile mapping projects.

OPMMS®

The Open Pit Mine Monitoring System (OPMMS®) is a solution composed by a software application and a long range Laser scanner, to continuously survey open pit mines slopes movements and deformation. OPMMS® remotely manage the 3D monitoring process, automatically providing automatic alerts due to geometrical changes and sharing the results of the 3D analysis.

TELEDYNE OPTECH

APPLICATIONS:

- AIRBORNE
- MOBILE
- TERRESTRIAL
- INDUSTRIAL
- MINING
- SPACE
- UNMANNED

COMPANY PROFILE

Teledyne Optech has led the world in the design and manufacture of advanced lidar instruments for more than 45 years. Widely recognized for its technological depth, the company has decades of experience in lidar, photogrammetry and in auxiliary technologies such as GPS integration and waveform digitization. Known globally for reliable and innovative products, Teledyne Optech offers standalone or fully integrated lidar and camera solutions to meet your airborne, mobile mapping, UAV and terrestrial laser scanning needs.

Visit www.teledyneoptech.com to see the latest solutions such as the ALTM Galaxy T2000 offering true 2MHz points on the ground and first time ever dual sensor mounting capability with the G2 Sensor System providing true 4MHz points on the ground or the innovative Compact Lidar suite of products featuring CL-360 with full 360 degree scanning and no blind spots.

TELEDYNE OPTECH
Everywhere**you**look™

Founded 1974

250+ Employees

300 Interchange Way

Vaughan, Ontario, Canada

Teledyneoptech.com

Hyper-Realistic Mapping With Galaxy G2 Sensor System And Galaxy T2000

THE GALAXY G2 SENSOR SYSTEM is a ground-breaking advance for Teledyne Optech. Integrating two advanced Galaxy T2000 or Galaxy PRIME on a single system, G2 operators can survey in high definition and capture more of their targets than ever before, while maintaining the flexibility to split the sensors and use them for separate projects.

TRUE 4-MHZ MAPPING The most obvious benefit of the G2 is its extremely high measurement rate. Using two 2-MHz GalaxyT2000s, the G2 paints the ground with 4 million true measurements per second, providing unprecedented point density. Notably, 4 MHz is the system's "real" on-the-ground measurement rate thanks to the Galaxy's oscillating scanner that keeps all of the points focused on the ground.

THE NEW GALAXY T2000 boasts a true 2 MHz ground sample rate with 100% of the points on the ground, extended range performance for increased productivity and faster scan rate to distribute points more efficiently. Teledyne Optech's signature SwathTrak with variable field of view provides more scanning efficiency over fixed field of view designs and PulseTrak enables continuous operating envelope for maximum collection efficiency regardless of terrain.

Increased energy density and vegetation penetration are realized through T2000's small beam divergence and data fidelity is increased for energy density and feature identification through 8 discrete returns with 8 intensity measures.

GEOCUE GROUP

APPLICATIONS:

- AIRBORNE
- CONSULTING
- MAPPING
- MINING
- PROCESSING
- SURVEYING
- TELECOM
- UNMANNED

COMPANY PROFILE

GeoCue Group was founded in 2003 by a group of engineers with extensive experience in developing hardware and software solutions for primary remote-sensed data acquisition. Our initial products were aimed at reducing schedule and cost risk in geospatial production workflows by providing organizational, productivity and data management tools for base geospatial data production. These tools have been realized as the GeoCue product family. Today GeoCue workflow management tools are used by a majority of North American geospatial production shops. In 2005, GeoCue began selling and supporting Terrasolid tools for kinematic lidar data production. This was followed in 2009 by our acquisition of QCoherent Software LLC, the creator of the point cloud exploitation toolset, LP360. Today GeoCue is the largest supplier of kinematic lidar processing tools in North America and LP360 is the world's most widely used tool for exploiting point cloud data.

Founded 2003

11-50 Employees

Huntsville, Alabama

geocue.com

True View

Leveraging our expertise in production, risk reduction, and point cloud processing tools, we are continuing to bring new services and products to market to provide surveyors and other geomatics professionals exciting tools for geospatial data extraction using low cost drones including Loki, our plug-and-play PPK direct positioning system, and now our new True View lidar/Imagery fusion sensors.

True View sensors offer surveyors an innovative lidar + dual oblique mapping camera configuration integrated in a single lightweight payload for use on commercial drone platforms. True View allows for fast, easy automated generation of true 3D colorized point clouds, oblique imagery and orthophotos from a single flight. The first sensor of the product line, the True View 410, is the industry's first integrated lidar/camera fusion platform designed from the ground up to generate high accuracy 3D colorized lidar point clouds. Featuring dual GeoCue Mapping Cameras, a Quanergy M8 Ultra laser scanner and Applanix Position and Orientation System (POS), the result is a true 3D imaging sensor. With its wide 120° fused field of view, the True View 410 provides high efficiency 3D color mapping with vegetation penetration in a payload package with a mass of about 2 kg.

In addition to its advanced fusion technology, the True View 410 includes a revolutionary business model option. Customers can purchase the complete system (hardware and full workflow software) as a standard purchase or enroll in a subscription service. The base subscription includes enough processing minutes to complete about 20 projects of 50 acres each. Additional processing is purchased by the minute.

TrueView
GeoCue

UAS LIDAR/Imagery Sensor Fusion
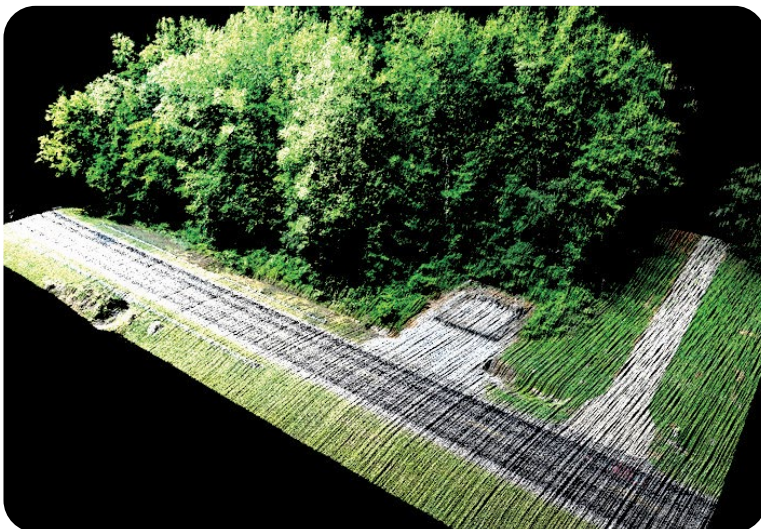
Dual Cameras

LIDAR Scanner

Google Processor

TrueTrack Flightlines

Workflow Software

Applanix Positioning

The True View 410 is the industry's first integrated LIDAR/camera fusion platform designed from the ground up to generate high accuracy 3D colorized LIDAR point clouds. Featuring dual GeoCue Mapping Cameras, a Quanergy M8 Ultra laser scanner and Applanix Position and Orientation System (POS), the result is a true 3D imaging sensor. With its wide 120° fused field of view, the True View 410 provides high efficiency 3D color mapping with vegetation penetration in a payload package of 2.2 kg.
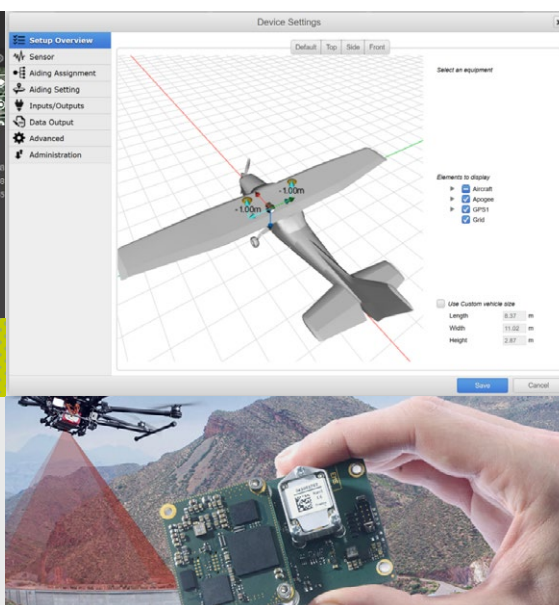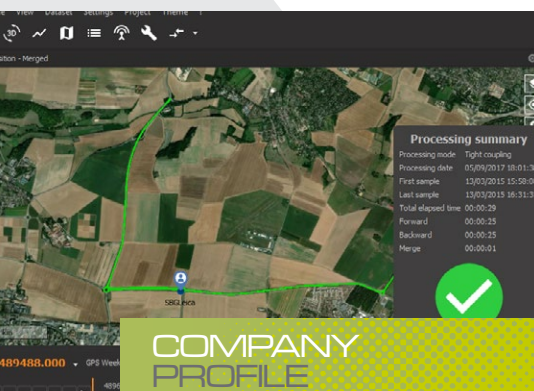
GeoCue
Group
www.GeoCue.com

SBG SYSTEMS

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 Huntington Beach, CA. SBG Systems offers a complete line of inertial sensors, such as Attitude and Heading Reference System (AHRS) or Inertial Measurement Unit (IMU), 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 industrial, defense & research projects such as unmanned vehicle control, antenna tracking, camera stabilization, and 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

Huntington Beach, CA

sbg-systems.com

Direct Georeferencing Solution

Quanta embeds high-quality gyroscopes and accelerometers that are factory calibrated from -40 to +85°C. It also integrates an RTK GNSS receiver providing a centimetric position. The internal Extended Kalman Filter fuses inertial and GNSS data for the highest performance in the most challenging conditions. Quanta can be integrated within a UAV or a land based mobile mapping solution, delivering real-time and post-processing data thanks to Qinertia PPK software.

Lidar & Photogrammetry—UAV or Land based Applications

Quanta directly and precisely geotags your point cloud whether your platform is a UAV or a car. In UAV-based photogrammetry, it also reduces the need for ground control points and overlapping thanks to precise orientation and position data.

One Year Free Post-processing with Qinertia UAV

Both Quanta model embeds a data logger for post-processing. Qinertia post-processing software enhances SBG INS performance by post-processing inertial data with raw GNSS observables. One year of Qinertia is offered for UAV applications.

Single or Dual Antenna

If a single antenna solution tends to be more practical, the dual antenna mode allows a more precise heading for low dynamics flights (pipes or electrical lines surveys). Quanta is a powerful and flexible INS+GNSS designed to be tightly integrated in mobile mapping solutions whether they are aerial or land. Quanta combines excellent orientation and navigation data in real-time with a powerful and easy-to-use post-processing software.

Quanta

Direct Georeferencing Solution INS + GNSS

Two levels of Accuracy

z

x   y

APPLANIX

COMPANY PROFILE

Applanix Corporation builds, delivers, and supports products and solutions designed specifically for the unmanned aerial survey industry. Applanix Direct Georeferencing technology works with UAV mapping sensors—including cameras, Light Detection and Ranging (LiDAR), and hyperspectral sensors, to perform highly efficient mapping and surveying from a UAV. Direct Georeferencing drastically reduces or even entirely eliminates the use of Ground Control Points (GCPs), thus shortening both the flight and processing time required to generate final map products. Since 2003, Applanix has been a wholly owned subsidiary of Trimble.

Founded 1991

51-200 Employees

Ontario, Canada

applanix.com

APX-18 UAV

The Trimble APX-18 UAV is an OEM GNSS Inertial solution with dual GNSS antenna input, designed to georeference lidar and other imaging data when collected from Unmanned Aerial Vehicles (UAV) at low speeds or when hovering. Comprised of a small single OEM board containing a precision GNSS receiver with two antenna heading and inertial sensor components plus POSPac UAV Differential GNSS-Inertial office software, the Trimble APX-18 UAV produces a highly accurate position and orientation solution for directly georeferencing lidar point clouds and imagery.

High accuracy, extremely small package

Measuring just 100 x 60 mm and weighing only 62 grams, the APX-18 UAV provides unparalleled performance in an extremely small package. With the included POSPac UAV postmission software, it produces a highly accurate position and orientation solution for direct georeferencing of cameras, lidars and other UAS sensors.

Key features:

- High-performance Direct Georeferencing solution for improved efficiency and accuracy of mapping from small Unmanned Aerial Vehicles
  - Reduce/eliminate GCP's
  - Reduce sidelap
  - Accurate lidar georeferencing
  - Instant alignment through dual GNSS antenna heading
- Compact single-board OEM module complete with survey-grade multifrequency GNSS receiver and MEMS inertial components
- Applanix IN-Fusion™ GNSS-Inertial and SmartCal™ compensation technology for superior position and orientation performance
- POSPac UAV Differential GNSS Inertial post-processing software for highest accuracy
- RTK real-time position for precision landing applications
- Supports all common RTK corrections such as CMR, CMR+, RTCM
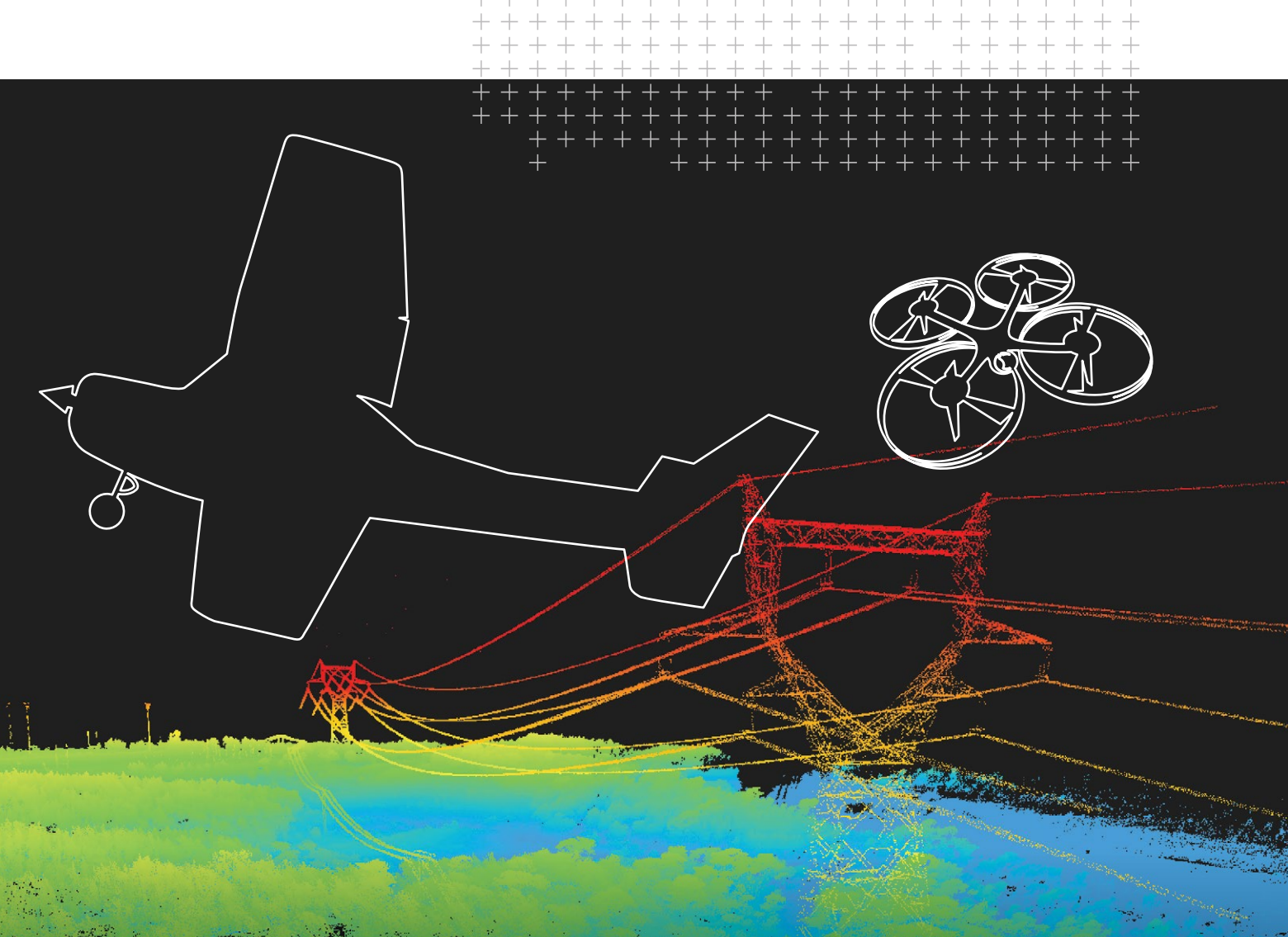
Reduce the cost & improve the accuracy of airborne mapping. No matter what you fly!

▶ Direct Georeferencing solutions for manned and unmanned platforms.

Applanix Corporation
85 Leek Crescent, Richmond Hill, ON L4B 3B3 Canada
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applanix™ DG™

READY WILLING ABLE

The SWAT Team of Lidar

GEO1 provides rapid response aerial lidar and imaging services globally
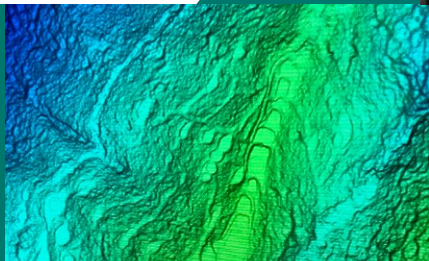
In 2009, a client request for high resolution video of an electrical transmission circuit drove this group of aerial cinematography experts to consider and eventually adopt lidar for 3D visualization. Having honed their craft within the high-stakes world of entertainment and visual effects, GEO1 applies world-class technique and special forces style deployment capabilities to exotic surveying and mapping projects.

BY JEFF **WINKE**

Southern California-based GEO1 is an intelligent aerial sensing firm that uses high-density lidar, high-resolution imagery, and video with augmented reality technology, to execute challenging land surveying and mapping projects. GEO1 is often called upon to assess complex landscapes, from the world's tallest mountains to remote volcanoes; from busy airport runways to structures hidden beneath dense jungle canopy.

Headed by aerial film industry veteran Ron Chapple, GEO1 was founded in 2015 as the survey and mapping division of Aerial Filmworks. Aerial Filmworks, the parent company, provides gyro-stabilized Cineflex and Shotover camera systems for entertainment, advertising and corporate clients worldwide. Extensive helicopter filming experience, full-time camera operators, tech support and more than 25 years of location work positioned Aerial Filmworks as a leader in aerial cinematography.

GEO1 provides the newest Riegl lidar and Phase One high resolution imaging technology for utility corridor, archeology, and visual effects (VFX) projects.

"We first got involved with survey work through a client request," stated Ron Chapple, founder and CEO, GEO1. "We had a client that asked for high resolution video of an electrical transmission circuit. I was intrigued by the new business opportunity as we delivered what was likely the first 'feature film' quality video of electrical infrastructure. We all laughed that we were going to win an Oscar for the best electric utility inspection film! From

Ron Chapple working in the Arctic Circle on a nature documentary for National Geographic.

there, we built the first commercially available device to overlay date/time and positional information.

"The idea of creating 3D visualization was always intriguing and finding new ways, such as lidar, to explore and document landscapes that we were already documenting with gyro-stabilized video seemed like a natural extension."

As part of its decision-making process when looking to add new technology, the GEO1 team tries to adopt a fresh perspective.

"In our first meeting with a lidar manufacturer, we told the tech rep that we wanted to find a way minimize the use of GPS base stations, and they said 'No way, not possible,' Chapple said. " Nevertheless, in the past three years, the GEO1 team have been able to dramatically increase their efficiency thanks to the Trimble AV39 antenna and Trimble's PP-RTX subscription."

The Trimble AV39 GNSS Antenna has been designed to support centimeter level accuracy for airborne applications

by using Applanix POS AV software to process the airborne sensor data. The antenna is fully certified by the FAA for aircraft installations.

The Trimble PP-RTX is a point-to-point communications protocol designed to provide real-time, centimeter-level positions through its satellite-delivered global positioning service. The subscription service provides the geographic reach needed for capturing the data.

With its roots and experience in the aerial cinema industry, GEO1 has needed to produce quality work quickly in challenging environments.

According to Chapple, the cinema industry is the definition of urgency. "You don't tell a film director that the shoot needs to be delayed because of logistics or equipment issues. On a feature film set, there could literally be hundreds of extras, expensive props and multiple camera crews waiting on the helicopter to be in position.

"In aerial filming, the aerial director creates the optimal shot, not unlike

making the optimal flight path for an electrical corridor scan. The resulting data is then edited by another team, music added, and the final story (or deliverable) is shared with the audience. I view lidar data in much the same way… there's a crew that pulls together all the technical details and acquires the information. Once the data files are processed, analyzed, and prepared, they become our deliverable to a desired audience. Understanding the workflow and making sure the film director or processing team has excellent information with lots of options is our standard operating procedure."

Ron Chapple's business roots helped shape the current processes found in the company.

"I started my business career as a commercial and advertising photographer and then transitioned into aerial cinematography about 15 years ago," Chapple said. "My company, Aerial Filmworks, worked on numerous nature documentary projects for National Geographic, BBC, and the National Park

Service along with a few feature films and commercial projects."

According to Chapple, the GEO1 team is the reason for continual success. Phil Carter, aerial systems director, joined the company six years ago prior to the transition period from Aerial Filmworks to GEO1.

The nature documentary and environmental projects were easy to relate to for new prospective clients, which helped Aerial Filmworks' business growth.

"Managing complex logistics, travel, and shipping is in our DNA," stated Carter. "In our time working in aerial cinema, we worked in every US state and 30+ countries, so we knew we needed to build lightweight and durable sensor integrations. All of our equipment cases weigh under 70 pounds in order to be checked as excess baggage for international projects. We've also become well versed in exporting gear internationally using ATA carnets, and purchased hardware that does not require special regulatory compliance, which would potentially cause delays in rapid response situations. From our aerial cinema days, we were just about on a first name basis with Customs and Border Protection (CBP) officers at a few airports!"

The company also makes sure its equipment uses standard helicopter mounts with FAA and EASA STC approvals. Carter also explains that their experience working internationally means that they have had the opportunity to work with numerous helicopter providers in a variety of markets, which simplifies the planning and quote process.

In building the GEO1 team, Chapple sought out remote sensing operators who are technicians first, and all his operators have worked first in the cinema industry.

"We look for the rare person that has helicopter, technical trouble-shooting, and creative experience along with a diligent work ethic," Chapple said. "The ability to deploy quickly also runs deep in our organization. When I started in business many years ago, I once waited 20 minutes to call back a potential client and when I returned the call, they said 'too late, we already gave the project to someone else.' I vowed to never let that happen again."

Ron Chapple, working on a helicopter-based aerial filming project.

Carter added, "When our gear comes back from an acquisition, we do a clean-up and re-pack to be ready for the next project. In the past few weeks, we traveled from Los Angeles to Bogotá with less than 48-hours notice. The Colombia project was complex, as the client added a late request for 4-band imagery after our arrival in country. So, within 10 hours, we orchestrated the logistics to have one of our team members jump on a flight and hand-deliver a Phase One iXU-RS1000 4-Band camera system to our crew in Colombia, which we were then able to integrate on site the next day.

We have learned to keep our passports current and a bag packed!"

GEO1 works both as an acquisition partner and a prime contractor for a range of survey/mapping and data clients, both small and large. Three years ago, the company developed the industry's first dual sensor pod with two Riegl VUX1LR lidar units and Phase One cameras which created a new lidar standard for the electric utility industry. Last year, demand enabled GEO1 to bring on a dedicated team of geospatial professionals for data processing and analytics. GEO1 now provides a range of services for smaller clients that need a full-service approach.

"Our team is amazing," states Chapple, "our ability to generate new ideas and new perspectives has expanded exponentially."

GEO1 has also extended their lidar capabilities to provide UAS-based data collection with the Riegl miniVUX1. The company's current business is 50% electrical corridor work and 50% "small" wide area up to around 100,000 acres.
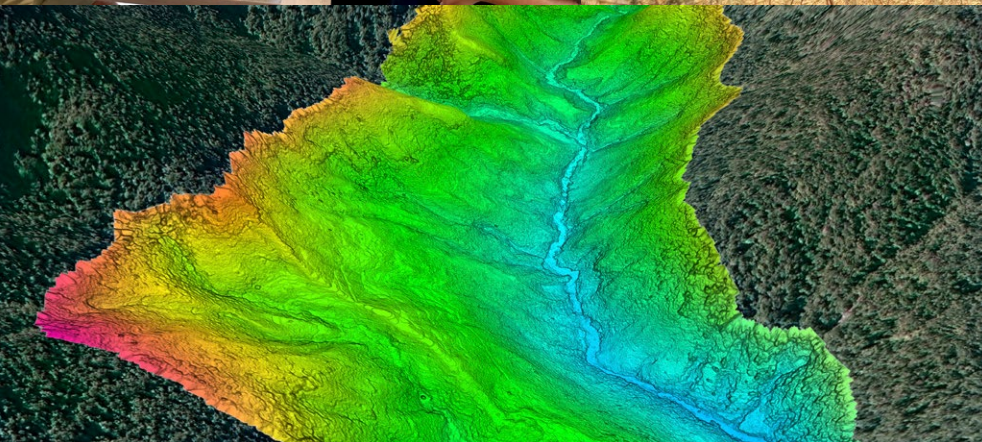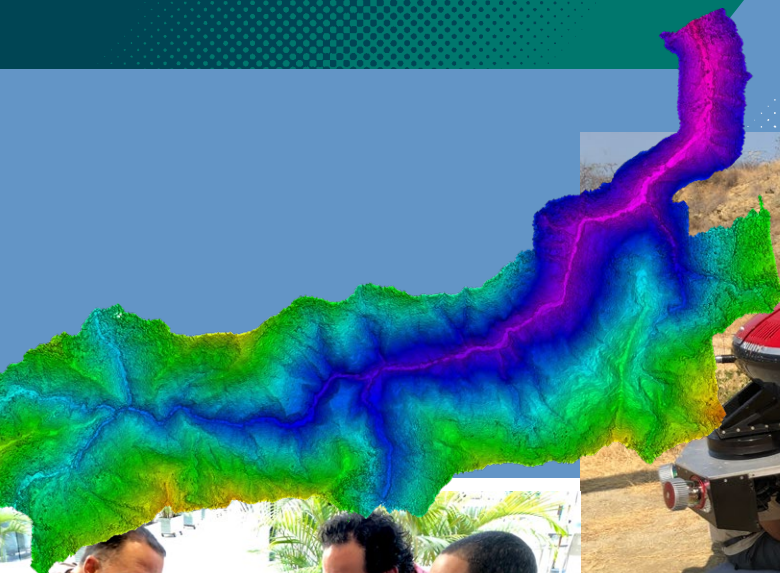
Phil Carter, Aerial Systems Director (right), and Francisco Forero, Business development Director of GEO1 (left) at the moment of discovery of lost civilizations with Santiago Pelaez, Director of the Global Heritage Fund.

Almost all of the work is helicopter based and the wide area projects are in challenging locations, where clouds, weather, and terrain can be significant factors. Their lidar data is used for archeological discovery, vegetation management, electric conductor engineering analysis, highway corridor mapping, urban planning, and terrain modeling.

As Chapple said: "We are always working on interesting projects with inspirational clients! We enjoy the challenge of creating solutions for unique projects!"

Here are several interesting GEO1 projects:

National Geographic: Lost Cities

GEO1 ventured into the depths of the Colombian rainforest to both map an existing archeological site and explore for undiscovered settlements. The work centered on "Ciudad Perdida," a Tairona settlement, which was built around 600 A.D. in the northern regions of Colombia at the base of the world's largest coastal mountain. The company arranged the helicopter and planned the flight lines in conjunction with local archeologists. The flights followed difficult-to-traverse footpaths that climbed steeply into the jungles surrounding the native settlement. In addition, the in-house team processed the lidar data, built the digital terrain model, and delivered slope shade analytics. GEO1's reward was the discovery of six previously unknown settlements!

The lidar findings became the basis for the *National Geographic* explorer Albert Lin hosted television program, *"Lost Cities with Albert Lin."*
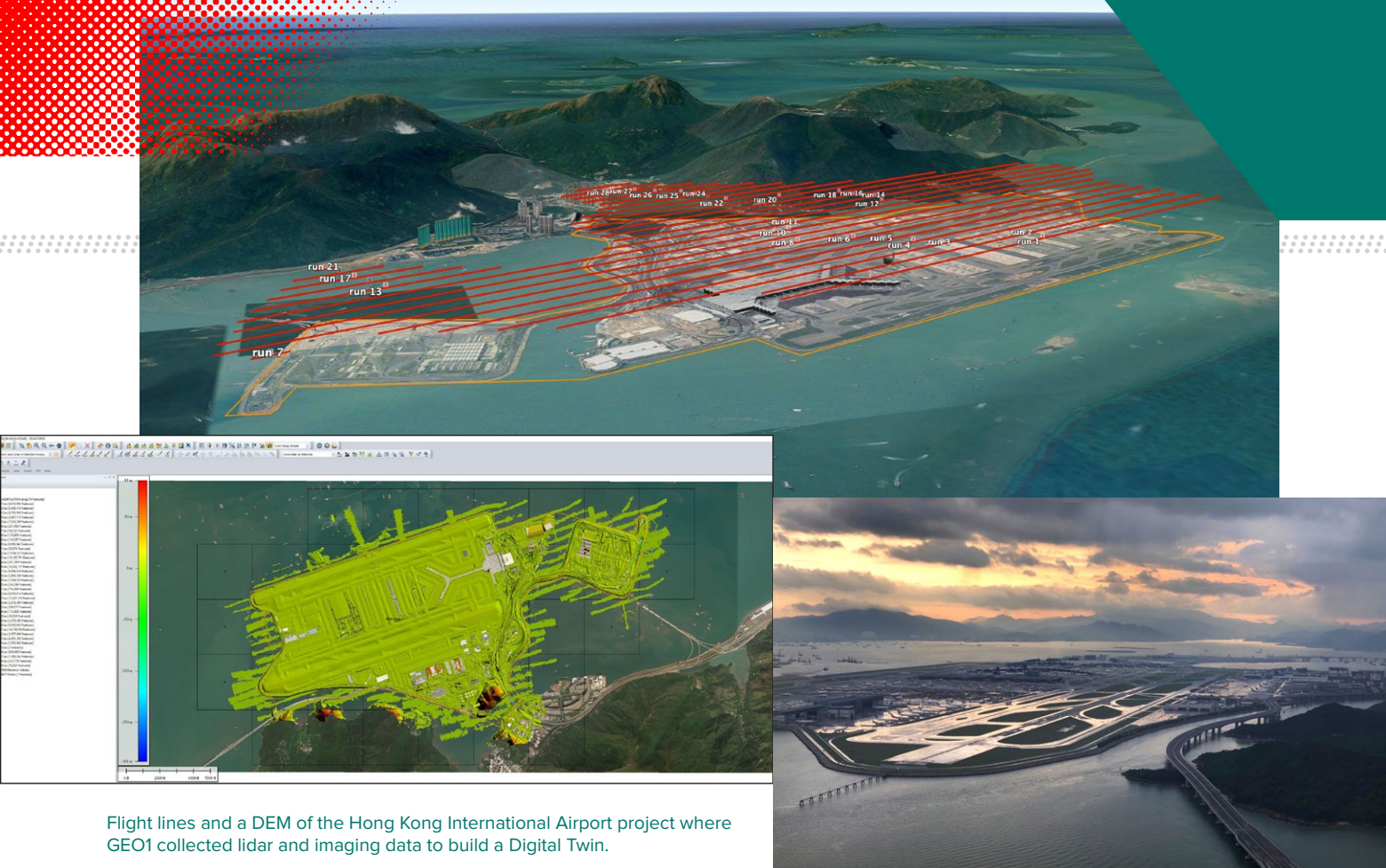
Flight lines and a DEM of the Hong Kong International Airport project where GEO1 collected lidar and imaging data to build a Digital Twin.

Hong Kong International Airport

The Hong Kong International Airport (HKIA) contracted GEO1 to deliver high density lidar data and imagery to build a full "Digital Twin" 3D visualization. Considering an international airport is a massive dynamic facility that needs clockwork-like functionality to serve the traveling customer, a "Digital Twin" allows airport managers to view the eighth-busiest airport in the world as an interactive environment from any angle at any time. HKIA has two runways with a third runway under construction.

The digital model can be used to simulate an emergency event, or as a cost-effective simulator to train new employees on where to safely drive airport service roads, or for better visualization of new construction.

The lidar data and images acquired by GEO1 were shipped directly to GeoSim, based in Vancouver, BC, Canada, to build a full high resolution "Digital Twin." In addition, GEO1 delivered calibrated LAS files and a colorized point cloud with 1-3cm accuracy directly to the Hong King Airport Authority for use with their new holographic viewing table.

To capture the data, GEO1 team worked closely with the helicopter company and the Hong Kong Aviation Authority to develop a flight plan covering 4,000 acres of airport property that would meet air traffic control safety protocol while delivering the best possible results. Air Traffic Control granted permission for the lidar and imaging flights to be flown from the hours of 6:30am – 7:30am Monday through Friday.

"Being granted permission to fly just one hour per day was a unique challenge," stated Carter, the aerial director for the project. "Logistically that meant leaving the hotel at 4am to prep the helicopter, and then de-rigging after each mission so the helicopter was available for other flights during the day. We then needed to re-rig the aircraft late in the afternoon for our next day's flight."

Lidar data was acquired with the Riegl VQ480II and Applanix AV610 IMU with imagery from the Phase One 4-Band iXU-RS1000 system during the first set of flight sessions. A follow-up mission with GEO1's new MultiCAM system was subsequently flown to acquire 150-mega-pixel oblique and nadir imagery. The MultiCAM is another first for the GEO1 team with a successful integration of six Phase One cameras at nadir and oblique angles. All cameras trigger simultaneously to acquire 800 megabytes of combined data with every shutter activation.

In addition, both of GEO1's sensor pods needed to be approved for use on the helicopter by the Hong Kong Civil Aviation Department (HKCAD). Mechanical drawings and manufacturer certifications were submitted to a third-party engineering firm, and on-site radio frequency interference tests were successfully conducted. At this time, GEO1 believes that their sensors are the only approved lidar and imaging pods in Hong Kong.

GEO1 collected high density lidar data and imagery for Quantum Spatial during the active volcanic eruption of Kilauea.

Kilauea Volcano, Hawaii

Lidar and imaging data for the Kilauea Volcano was captured for Quantum Spatial (an NV5 Company) while the volcano was active in 2018, and a follow-up baseline survey was conducted a year later in 2019. The data was collected on behalf of the United States Geological Survey (USGS), the Hawaiian Volcanic Observatory, and as a test project for the new USGS Rapid Imagery Response program.

The initial acquisition took place during the active volcano eruption, with lava devastating neighborhoods on a daily basis. Five distinct locations, covering an area of 57 square miles, were targeted. The project required 11 missions over the course of six days, operating, at times, as low as 500 feet above the ground and above active flows and nearby erupting calderas. With a need for a quick turnaround, a Quantum Spatial analyst accompanied the GEO1 flight crew on location.

One of the unique requirements was the delivery of LAS format files within 10 hours after each mission. LAS file format is an open, binary format designed for the interchange and archiving of lidar point cloud data. Quantum Spatial's team used high-performance workstations for immediate processing of the data. The processed data was then sent via FTP to Cold Regions Research and Engineering Laboratory (CRREL) for cloud processing of a digital elevation model to be uploaded within another 10 hours.

In 2019, GEO1 with Quantum Spatial acquired a much larger and higher density data set as a baseline for the new landscapes created during the 2018 eruption. On the last flight of the 2019 project, the GEO1 crew alerted the science team to the discovery of a small 10-foot pond at the bottom of the Halemaumau Crater. The pond has since expanded to a lake that is 600 feet long and over 60 feet deep, and is the first time in recorded history that a lake has been observed in the crater.

Airborne lidar data and imagery analysis will help first responders, scientists, and government agencies monitor conditions, predict future lava flows and protect Hawaiian residents from the Kilauea volcano, which has been erupting since May 3, 2018 and has changed the topography as fissures emerge and lava flows extend to the ocean.

Southern United States Border Wall

The GEO1 shared a **Pulitzer for Explanatory Reporting** with the USA Today team for their work on an innovative documentary project. GEO1 delivered almost 2,000 miles of geo-referenced video, lidar data, and high resolution imaging for "The Wall" project. The interdisciplinary endeavor used virtual reality, aerial video, 360-degree video, documentary video, photos, podcasts and
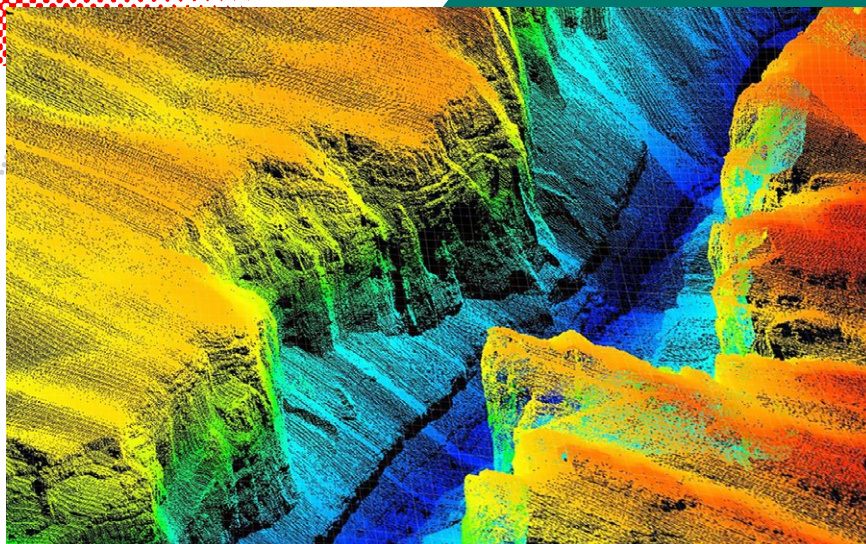
GEO1 flew the entire USA/Mexico border for USA Today with HD video, lidar, and imaging sensors. The team shared a Pulitzer Prize for the documentary work.

interactive maps—as well as more than a dozen stories—to examine and document the border between the USA and Mexico.

"The border between the USA and Mexico is truly amazing, from the meandering deltas at the Gulf of Mexico through rugged canyon lands in Texas, and through dense urban neighborhoods into the Pacific Ocean." states Ron Chapple, CEO of GEO1. In addition to navigating the complex border, Chapple and the GEO1 team filed daily reports with the US Customs and Border Patrol and military agencies to alert law enforcement to their presence at any given time.

Once the lidar and imaging data was complete, the USA Today team built a 3D environment for viewing in Virtual Reality goggles. The geo-referenced video was uploaded to the documentary web site with links for the user to click anywhere on the route to view the video. GEO1 also provided a custom extension to the Global Mapper application that merged the video timecode and meta-data to display the location of the video.

• • •

Since its first day, GEO1 accepted the necessary risks to build a business based on providing the newest lidar and high resolution imaging technology to clients.

"We have had no funding from a private equity firm, venture firm, or angel investor," stated Chapple. "Our first lidar scanner was purchased with a 2nd mortgage on my house and a personal guarantee. After that purchase, we were successful in booking absolutely $0—zero dollars—in our first year of business. Definitely an eye-opener into the challenges of starting a new business, but we were confident that we were moving in the right direction!"

Within 18 months of that first invest-ment, GEO1 began receiving projects and experienced double-digit year over year growth. The company now owns three Riegl scanners, three Applanix IMUs, and nine Phase One cameras plus meteorological sensors, field support vehicles, and multiple workstations.

GEO1 has successfully used their years of aerial cinematography experi-ence to create what they consider the geo-spatial business of the future.

According to Chapple, "What drives our team is being innovative in how we use lidar and imaging data to contribute to a sustainable future. Still, the usual challenges of developing a business, learn-ing new software, and incorporating new workflows are always part of the mix."

Nevertheless, it appears that with a history of growth and a promising future ahead, these challenges are ones that Chapple and GEO1 gladly embrace. ◫

Jeff Winke is the Associate Editor of the magazine.

GEODETICS

APPLICATIONS:

- FORESTRY
- TOPOGRAPHY
- TRANSPORT
- AGRICULTURE
- CONSTRUCTION
- MINING
- URBAN PLANNING
- OIL & GAS

COMPANY PROFILE

Geodetics is the go-to provider for lidar Drone mapping, Assured PNT and sensor fusion for mobile applications in the air, on land and at sea. Founded in 1999, Geodetics has been delivering state-of-the-art products to its commercial and defense customers for over two decades. Geodetics' technical expertise spans lidar drone mapping, Positioning, Navigation and Timing solutions as well as advanced sensor fusion technologies. Geodetics' team consists of innovators, technical experts and partners focused on making technology accessible to customers with mission critical challenges. With our core competencies in Advanced algorithms, data and sensor fusion and national security measures, Geodetics offers cost-efficient products that can be tailored to support our customer's unique applications.

GEODETICS INCORPORATED | Precision in Motion.

Founded 1999

25–50 Employees

San Diego, California

geodetics.com

State-of-the-Art Lidar and Photogrammetry Solutions

Geodetics' Geo-MMS Mobile Mapping System is a cost-effective modular system for Drone and Vehicle-based Photogrammetry, lidar mapping and creation of RGB/multi-spectral colorized lidar point clouds. At the heart of Geo-MMS is Geodetics' Geo-MMS Navigator, a dual-antenna inertial navigation system integrated with lidar, RGB, multi-spectral and hyper-spectral sensors. The Geo-MMS Navigator was designed from the ground up by Geodetics specifically for mobile mapping applications, leveraging our expertise from years of delivering high-performance navigators to our defense customers. The Geo-MMS Navigator offers many features unique to mobile mapping applications and supports dual GNSS receivers, a variety of IMU grades, and includes our advanced Extended Kalman filter software to optimally integrate the sensor data. When your workflow moves to post-processing, Geodetics' extensive "one-click" processing suite of software provides a powerful, easy to use toolbox for your mobile mapping applications.

Through the advancement of technologies in UAV lidar mobile mapping systems which output LAS files, Geo-MMS users can easily create DEM/DTM/DSM (surface models), geospatially corrected aerial images, 3D building models, contour maps, planimetric features and volumetric surveys—just to name a few applications. The Geo-MMS family includes 1) Geo-Photomap, which tightly integrates GPS/IMU with RGB/multispectral imagery resulting in directly georeferenced images enabling corridor mapping and vertical mapping. 2) Geo-MMS lidar, our lidar payload, offers a wide range of lidar sensors with ranges from 50 – 600 meters.

3) Our Point&Pixel technology provides a tight coupling of RGB/Multispectral images and lidar sensor data delivering stunning colorized lidar points clouds. Geodetics' products and technologies advance the state-of-the-art, while offering significant time/cost savings to our customers.

YELLOWSCAN

APPLICATIONS:

- AIRBORNE
- CONSTRUCTION
- MAPPING
- MOBILE
- SURVEYING
- INSPECTION
- TRANSPORT
- UNMANNED

COMPANY PROFILE

YellowScan lidar products are fully-integrated systems designed for commercial UAV applications. Our lidar solutions include the laser scanner, IMU, GPS, embedded computer and batteries. The processing software provided enables the generation of a georeferenced point cloud in the projection of your choice. Output format is .LAS (lidar industry standard) or .TXT. YellowScan is committed to provide users with the most reliable fully-integrated lidar imaging systems and customer support for demanding UAV applications. Since 2012, the team's dedication to fulfill high resolution and high-quality survey requirements has fueled research and development. Our next generation of fully-integrated lidars are ergonomic, robust and easy-to-use, designed by surveyors to serve surveyors, civil engineers, archeologists and other professional users with a turn-key solution that can be mounted on most commercial-scale drones. The Mapper II, Ultra and YellowScan Vx models complete the "Just press the Yellow Button" product line, complementing the original YellowScan Surveyor, the successful world lightest fully integrated lidar for UAV.
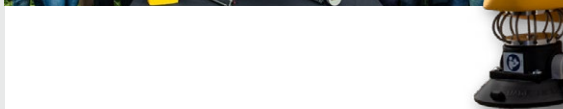
YellowScan

Founded 2005

25-50 Employees

Montferrier su lez, France

Utah, USA + Tokyo, Japan

Yellowscan-lidar.com

Fly & Drive

YellowScan Fly & Drive is a combo that can-do mobile mapping & aerial survey using the same lidar (Surveyor or Surveyor Ultra). It combines high resolution laser scanning and precise positioning to collect georeferenced point clouds for a wide range of applications. This will move the user into another level of possibilities and productivity. The swap can be done in less than 5 minutes. It reduces project duration through fast implementation, collection and data analysis.

Fly & Drive can be rapidly deployed on road vehicles as well as on any types of UAVs (multirotor, helicopter, VTOL or traditional fixed-wing), expanding the range of applications and thereby hastening your return on investment.

Fly & Drive is an extension of our Surveyor and Surveyor Ultra, consisting in set of mobile mapping gear: a pod, an adaptable bracket and a GNSS antenna.

The possibility to switch the lidar system from UAVs to land vehicles and vice versa, allows the user to perfectly complement a top view acquisition of building roofs with a detailed façade survey. Or, in a light forest, a canopy and tree trunks survey.

It also allows to survey flight restricted zones, such as urban areas, power plant, refineries and more. The main purpose of the point clouds you acquire with Fly & Drive are road, pipeline, renewable energy construction pre-survey or quarries in presence of vegetation.

As the swap is easy and fast to operate, both acquisitions can be done in 1 day.

Woolpert

- PHOTOGRAMMETRY
- ORTHOIMAGERY
- BATHYMETRY
- HYDROGRAPHY
- ACOUSTIC
- SURVEY
- CLOUD
- UAS

COMPANY PROFILE

ASPRS PRESIDENT JEFF LOVIN

Woolpert Senior Vice President and Market Director Jeff Lovin, CP, PS, will be named president of ASPRS at GeoWeek this year. Lovin has been with Woolpert for 33 years and has had the privilege of leading and serving multiple industry organizations.

"ASPRS is the original geospatial organization. Founded in 1934, it is responsible for our national standards and our credentials," Lovin said. "I've been very fortunate in my career to be a part of several organizations, but being elected as president of ASPRS ranks near the top for me. There is so much history with ASPRS, and if I look at the list of past presidents, it is quite humbling and an honor to join that list. It is a highlight of my professional career."

WOOLPERT
ARCHITECTURE | ENGINEERING | GEOSPATIAL

Founded 1911

1,000+ employees

30+ offices

Dayton, Ohio, USA

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jill.kelley@woolpert.com
Woolpert.com

Leading Lidar Data, Solutions Provider

We were there at the beginning and we'll be there till the end. Woolpert celebrated 50 years of geospatial excellence in 2019 by acquiring international geospatial firms, adding global geospatial experts and augmenting its strategic geospatial service offerings. These include aerial lidar, terrestrial lidar, bathymetry, hydrography, traditional land-based survey, acoustic survey, aeronautical survey, photogrammetry, remote sensing, sonar, data processing, GIS, UAS, subsurface utility engineering, floodplain mapping, coastal resilience, etc.

We also know all the right people. Woolpert is an Esri Silver Partner with Release Ready and ArcGIS Online specialty designations. As a Premier Google Partner, we were named Google Maps Partner of the Year in 2018 and formed our Google Cloud division in 2019. We also launched STREAM:RASTER™, a subscription software service to host and facilitate access to vast volumes of geospatial imagery in the cloud. Through these partnerships, we're able to bridge the high-level geographic science and software development of Esri with the ubiquitous client-facing expertise of Google.

And, oh yeah, we're also a full-service, 109-year-old architecture and engineering firm. How does that help our geospatial services? It provides a comprehensive, intimate understanding of those fundamental business needs and ensures we maintain successful, multifaceted relationships with local, state, federal, private and public customers around the world.

PICKETT AND ASSOCIATES

APPLICATIONS:

- AIRBORNE
- MAPPING
- IMAGERY
- UNMANNED
- SURVEYING
- CADD/GIS
- CONSULTING
- ENGINEERING

COMPANY PROFILE

Pickett provides aerial lidar, aerial mapping and imaging, land surveying, hydrographic surveying and engineering services to clients throughout the US and Caribbean. Pickett specializes in offering the simultaneous collection of high resolution 4-Band Aerial Imagery combined with engineering-grade airborne lidar, allowing us to turn around baseline imagery and lidar-derived data quickly and efficiently. We deliver CADD and GIS-ready products to meet unique client specifications. Our clients come to us for the most complex projects because of our proven track record of producing deliverables efficiently, safely, cost-effectively and on schedule. With over 50 years of experience, we have established ourselves as leaders and innovators in the surveying and geospatial industry. Contact us today to see how our geospatial services can benefit your next project.
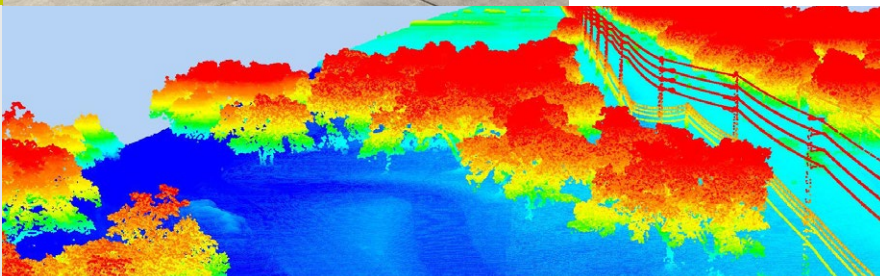

PICKETT

Incorporated 1963

51-200 Employees

Tampa, Florida, USA

PickettUSA.com

Advanced Geospatial Solutions

Our airborne lidar focuses on the energy, mining, and land development sectors. We specialize in small to medium-sized projects and can provide anything from raw data to a complete final product. Using data fusion, Pickett can merge results from ground surveys, hydrographic surveys, aerial lidar and digital imagery into a complete, all-encompassing map product.

The Teledyne Optech Galaxy PRIME lidar sensor is one of many tools we use for a myriad of lidar applications. When used in conjunction with our iXU-RS 1000 medium-format camera, this system produces a complete picture of site conditions.

In the energy sector, we perform aerial surveys of corridors with lengths of 1 mile to several hundred miles, with a point density of 50 points per square meter, or more. For the mining sector, we provide aerial surveys ranging in size from 1-acre stockpiles to several thousand acres, using the data to create digital surfaces and compute high-accuracy volumes for accounting purposes. Land development projects range in size from 20 acres to more than 100 square miles, finalizing into a detailed topographic survey.

We utilize a RIEGL terrestrial scanner for smaller projects where high-resolution, high-accuracy lidar data is required. In combination with the top-mounted DSLR camera, we can create photorealistic point clouds to survey and document as-built conditions of almost any feature.

Our aerial platform consists of a 2015 Cessna T-206H Turbo Station Air, modified with FAA approved camera ports for aerial surveys. Pickett has an FAA Section 333 exemption, and currently complies with FAA Part 107 regulations, to provide UAS services commercially.
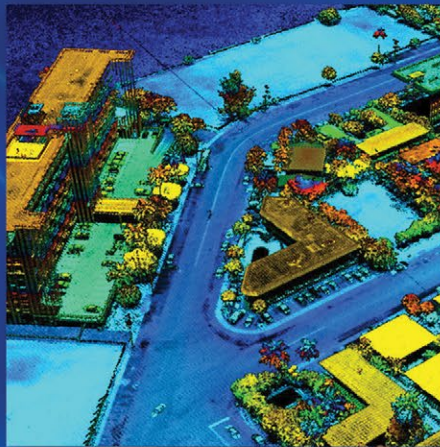
LiDAR USA

COMPANY PROFILE

We are an aggressive team of pioneers in geomatics searching for new, innovative, and affordable solutions. We build economical UAV & mobile mapping systems, that push technology to the edge using the latest tools for scanning, imaging, and navigation.

The idea to develop the Snoopy and ScanLook LiDAR systems came out of our need to find an affordable light weight solution that was easy to use and operate. We have developed solutions for indoors and outdoors. The key technologist and principal investigators are Daniel and Jeff Fagerman. We are experienced in photo control work with conventional total stations, levels, etc., and also with the latest GPS technology. We consider software development a particular interest and hardware integration something we excel at. We seek out ways to improve workflows using existing technology in an unconventional way.

Founded 1999
20+ Employees
Alabama, USA

lidarusa.com
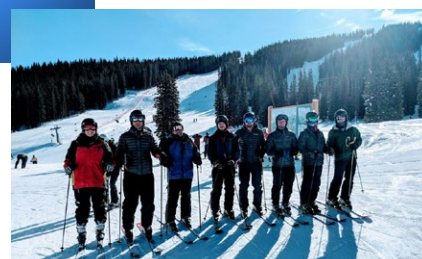
LiDAR USA—We Are LiDAR!

Snoopy A-Series HiWay Mapper HD + UAV Package

Weighing in at only 2.5kg, Snoopy A-Series is a smaller, evolved version of our Snoopy. This unit is also configurable but is designed to be an extremely accurate solution for multi-vehicle mounting. The A-Series is light-weight and easy to use. With just a click of a button on your smartphone you can scan anywhere with this little guy.

M200 Series Snoopy LiDAR Package

The M200 Snoopy Series LiDAR Package is designed specifically for the ever-popular DJI M200/M210 UAV. Custom designed for the Velodyne A-Series Scanner and weighing only 1.63kg, the M200 Snoopy Series is light, fast and easy to use. With deployment from an easy to carry case and just a click of a button on your smartphone, you are ready to scan. The M200 Snoopy Series is a smaller, evolved version of our Snoopy system. This unit is designed to be an affordable yet extremely accurate solution.

Revolution 60, 120 and HD

Ready-To-Fly-Ready-to-Scan package. Endless coordinate systems; LAS/LAZ, etc., formats; Control point registration; Point Cloud filtering; Coordinate measurement update tool.

We also offer the Snoopy Mini-VUX and VUX (RIEGL); Snoopy Dual-VUX (Riegl); SCANLOOK TreX, for Trimble shops; our PhaseOne Photogrammetry Package, a host of supporting products and more! Sensors we integrate and resell include the Velodyne Puck Hi-Res,Velodyne Puck LITE, Velodyne HDL-32E, Velodyne Puck. Sensors we inegrate include the FARO FOCUS 3D, Quanergy M8 and the Z+F Profiler.

One System.
Dual Use.
Yes, You Can Do Both!

Designed to easliy move from a UAV to a ground vehicle. Optimize your ROI.
Spend more time scanning, only 30 seconds to initialize.
We Make 3D Mapping Easy. Learn more on our website. www.LiDARUSA.com

YEARS
ANNIVERSARY
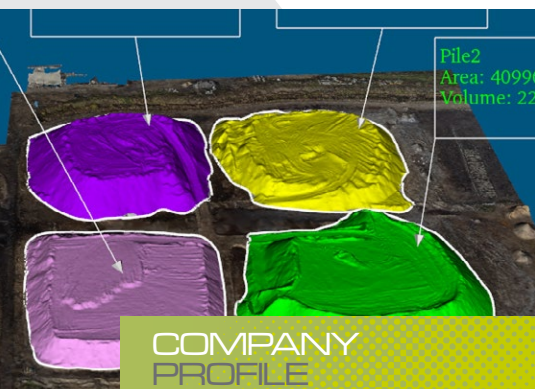CELEBRATION **20**

LiDAR USA
Fagerman Technologies Inc.

R RIEGL inside

Surveying Mapping Streetview Imaging
LiDAR USA
www.LiDARUSA.com   256.274.1616

VRMesh

APPLICATIONS

- LAND SURVEYING
- CONSTRUCTION
- ARCHITECTURE
- CIVIL ENGINEERING
- MINING/TUNNELING
- ENERGY/UTILITIES
- MANUFACTURING
- ENTERTAINMENT

Pile2
Area: 40996
Volume: 22

COMPANY PROFILE

Founded in 2003, VirtualGrid developed VRMesh, a point cloud and mesh processing software tool that covers point cloud classification, feature extraction, and point cloud meshing. VRMesh excels at handling large point clouds generated from LiDAR and UAV images. Also, as a technology pioneer in the field of point cloud meshing, VRMesh not only can produce an accurate mesh in great detail but also can create a solid mesh for visualization.

Today, the cutting-edge technology of VRMesh is well known in the geospatial and reverse engineering industries. It provides a streamlined workflow and the most comprehensive toolset to make engineers' jobs easier and to maximize productivity at work. VRMesh customers span across various industries such as land surveying, construction, mining, architecture, manufacturing, etc.

△△ **VR**Mesh

1400 112th Ave SE
Bellevue, WA 98004

www.vrmesh.com
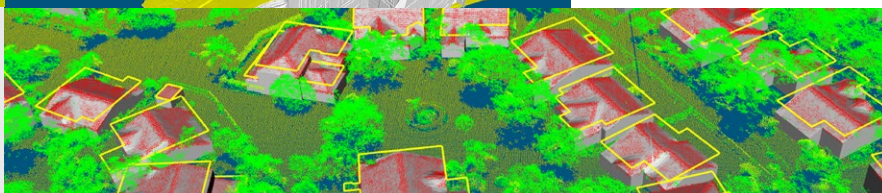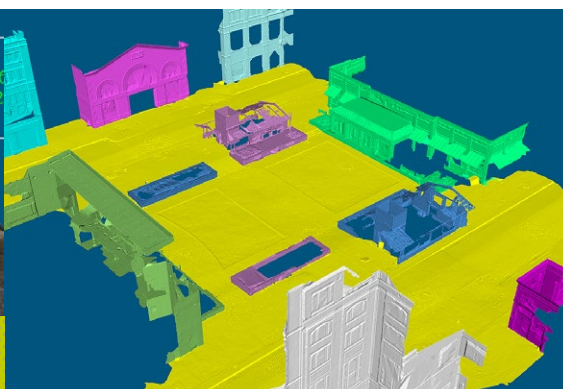
Point Cloud and Mesh Processing Software

Classification

Point Cloud Classification is easy to use. By adjusting only one parameter, roughness, you can easily detect vegetation and obtain clean surfaces. It automatically classifies point cloud which greatly eliminates the post-processing procedure. It works well even for extreme terrains.

Feature Extraction

Feature Extraction provides you with an essential tool kit to identify roof footprints, powerlines, poles, tree crowns, railways, curbs, pipes, all kinds of break lines and many more. It not only excels at detection variety and accuracy but also presents you with the flexibility between manual detection and auto detection.

Point Cloud to Mesh

Point Cloud to Mesh delivers unparalleled functionality and reliability. VRMesh can process point clouds in any size, and produce an accurate mesh with high details. It can also create a solid mesh for visualizing large-volume scans such as a construction site.

Mesh Editing

Mesh Editing summarizes a range of tools that enables you to design any shape and seam multiple parts into one mesh such as curbs, open-pit mines, etc. With the clay tools, you can simply brush to edit and update the surface mesh. Mesh Editing is an especially crucial resource for industries including but not limited to 3D mining and civil engineering.

Inspection

VRMesh supports IFC, STEP, and IGES files. With manual and auto registration tools, you can easily transform CAD files to match point clouds and meshes for inspection. VRMesh also equips you with many measurement tools such as tunnel cross-section deviation tools, water flow analysis, and volume calculation.
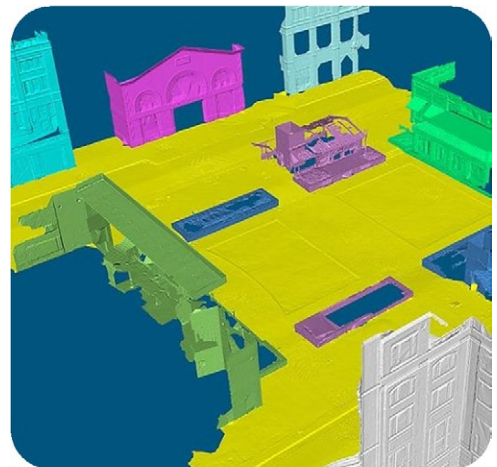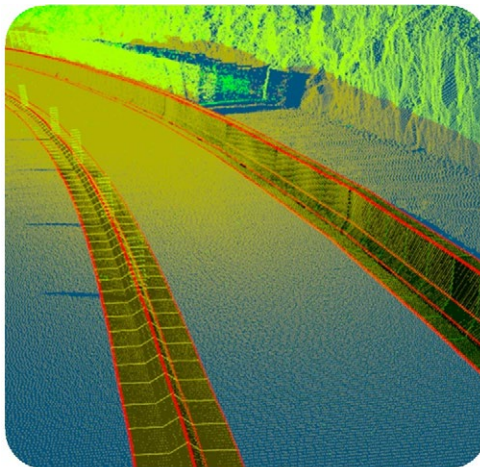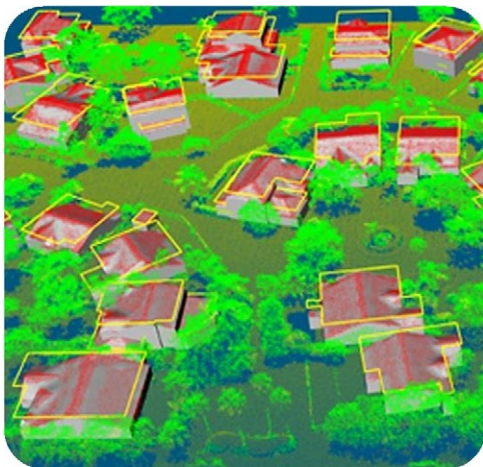
VRMesh

POINT CLOUD AND MESH PROCESSING SOFTWARE

Classification

Feature Extraction

Point Cloud to Mesh

Inspection

Golden Software

COMPANY PROFILE

Golden Software is the leading developer of affordable 2D and 3D scientific graphics and analytics software that transforms both simple and complex data into understandable visual tools such as maps, graphs and models. The company strives to create an ideal user experience by striking the perfect balance between powerful functionality and intuitive ease-of-use.

The Golden Software customer base includes over 100,000 users involved in environmental consulting, oil/gas/mineral exploration and extraction, engineering, applied science, business, education, and government in nearly 190 countries and territories.

Golden Software offers six intuitive data modeling, mapping, and graphing software tools: Surfer® for gridding, contouring and 3D surface mapping; Grapher™ for 2D and 3D graphing; Voxler® for 3D data visualization; Strater® for well log, borehole and cross section plotting; MapViewer™ for thematic mapping and spatial analysis; and Didger® for digitizing and coordinate conversion. Founded in 1983, the company is based in Golden, Colorado.

GOLDENSOFTWARE

809 14th St A
Golden, Colorado USA
Founded 1983
50-100 employees

www.goldensoftware.com
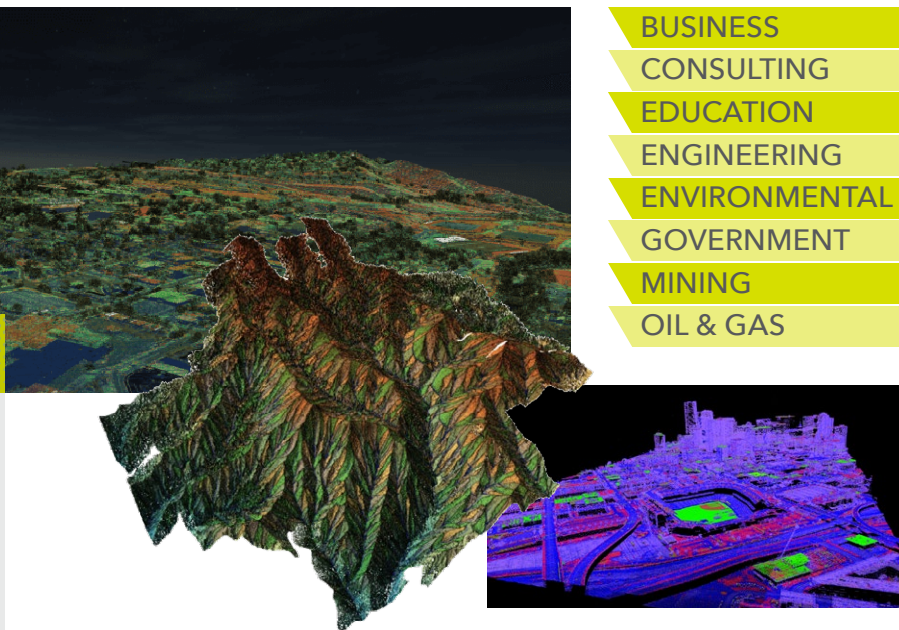
Surfer and Voxler

A Complete Surface and Subsurface Visualization Solution

Surfer is a robust gridding, contouring and 3D surface mapping software that routinely outperforms more expensive products. Used extensively by geologists, environmental consultants and geospatial professionals for more than 30 years, Surfer makes it easy to analyze and interpret even the most complex scientific data. It enables users to model their data sets, apply an array of advanced analytical tools, and graphically communicate the results in ways anyone can understand. Known for its fast and powerful interpolation algorithms, Surfer is used to visualize a variety of data sets including LiDAR point clouds, raster imagery, vector layers, well data, geophysical surveys, and geochemical data. Surfer can even be called from any automation compatible programming language to create scripts to automate repetitive or recurring tasks. In the latest version, Golden Software enhanced Surfer's gridding functionality for a faster and more powerful user experience.

Voxler empowers users to model data with striking clarity in every dimension and improves understanding of 3D data. With Voxler's extensive 3D modeling tools, users easily visualize multi-component data for geologic and geophysical models, contamination plumes, LiDAR point clouds, borehole models, or orebody deposit models. This user-friendly package improves understanding of 3D data by modeling the data set at any angle to pinpoint anomalies and discern patterns and trends. Voxler distinguishes areas of interest, highlights important information, and clearly communicates newfound knowledge to project stakeholders in true 3D space.

SimActive

APPLICATIONS

- AERIAL MAPPING
- DIGITAL SURFACE MODEL
- DIGITAL TERRAIN MODEL
- FEATURE CREATION
- MOSAIC CREATION
- PHOTOGRAMMETRY
- SATELLITE MAPPING
- UAV MAPPING

COMPANY PROFILE

SimActive is a leading developer of photogrammetry software since 2003. The company is the developer of Correlator3D, a patented end-to-end photogrammetry solution. SimActive introduced the first GPU-powered AT (Aerial Triangulation) and DSM (Digital Surface Model) generation engines in the industry, enabling multiple fold processing speed increases. Through continuous innovation and product updates since then, SimActive remains at the forefront of innovation as the technical standard the industry is measured against.

SimActive has been selling Correlator3D to leading mapping firms and government organizations around the world, offering cutting-edge photogrammetry software backed by exceptional customer support. For more information, visit www.simactive.com.

simactive

Montreal, Quebec

Canada

Founded 2003

11-50 employees

www.simactive.com

Correlator3D Software

Correlator3D is a patented end-to-end photogrammetry solution for the generation of high-quality geospatial data from satellite and aerial imagery, including UAVs. Correlator3D performs aerial triangulation (AT) and produces dense digital surface models (DSM), digital terrain models (DTM), point clouds, orthomosaics, 3D models and vectorized 3D features. Powered by GPU technology and multi-core CPUs, Correlator3D ensures matchless processing speed to support rapid production of large datasets.

Today, thousands of clients in over 100 countries use SimActive's Correlator3D. This includes government entities like the United States Army Corps of Engineers, and Fortune Global 500 companies like BHP Billiton and SNCF. SimActive's Correlator3D has received great praise from its global users for its exceptional precision, automation, unmatched processing speed and intuitive user interface. Whether clients need to increase productivity or integrate a new technology into their workflow, SimActive delivers.

SURESTAR LIDAR

APPLICATIONS:

AIRBORNE

AUTONOMOUS

MOBILE

NAVIGATION

ROBOTICS

TRANSPORT

UNMANNED

COMPANY PROFILE

Beijing SureStar Technology Co. Ltd. is a high-tech enterprise focused on lidar technology development and production. SureStar's product range is comprehensive, encompassing a full range of navigation and survey lidar development capabilities.

SureStar holds complete and comprehensive lidar core technologies and has reported nearly 100 intellectual property rights (patents, software copyrights and trademarks), including 18 invention patents, 3 PCT international patents, 16 utility model patents, 24 software copyrights, and more than 30 trademarks.

SureStar has continuously won different prizes since its establishment, including Beijing Space Innovation Enterprise Gold Award (2013), Zhongguancun Top 100 Most Innovative Enterprise (2014), Surveying and Mapping Science–Technology Progress First Prize (2015, 2016), Surveying and Mapping –Technology Progress Second Prize (2018), National Entrepreneurship and Innovation Week–Chinese Innovation Pioneer Top 20 (2017) and Beijing Independent Innovation Products (2016 – 2017).

SureStar

Founded 2005

200+ Employees

Beijing, China

isurestar.com

Continuous Innovation

SureStar embraces complete and comprehensive lidar core technologies. Quick roll-out of new products comes from a talented and fast-growing R&D team. SureStar has its headquarters and R&D center in Beijing, production facilities in Suzhou, and software team in Hefei (China). In 2018, SureStar set up a representative office in Wixom City, near Detroit, to provide timely technical support to North American clients. SureStar currently has more than 200 employees, of which more than 50% are involved in R&D and technical support.

As one of most important lidar providers for both mapping and automotive applications, Surestar has distributed lidar sensors into USA, Europe, Russia, Australia, South Korea and South East Asia. The Fortune 500 clients of SureStar include several Chinese leaders in power and transportation, and many big names in autonomous driving. SureStar sensors were also seen in Malaysia's first self-driving car in which Prime Minister Tun Dr Mahathir Mohamad took a ride on April 2019. Mid-2019, SureStar was notified that it had met the requirements of IATF16949:2016. This international standard was published in 2016 by the International Automotive Task Force to supersede ISO/TS 19649. The standard is aimed at the development of a quality management system that provides for continual improvement, emphasizing defect prevention and the reduction of variation and waste in the automotive industry supply chain. SureStar's commitment to automotive lidar is clear, while it continues to offer products across the lidar spectrum, including the rapidly growing UAV-lidar market.

SureStar
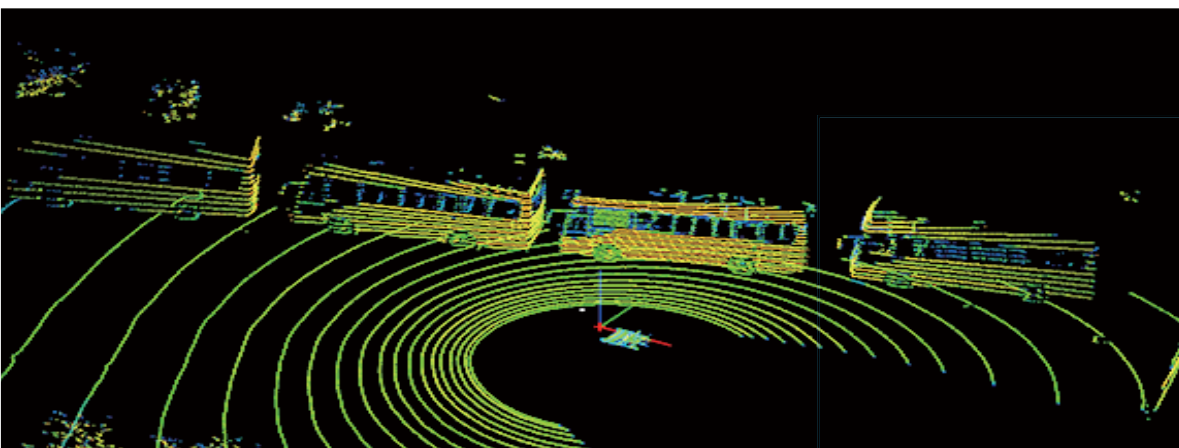
R-Fans

C-Fans

Mapping & Navigation LiDARS

Genius
1168 g

Magic
1180 g

Mini UAV LiDAR

-- Weight below 1.2 kg

-- Range beyond 200 m

Sky-Lark
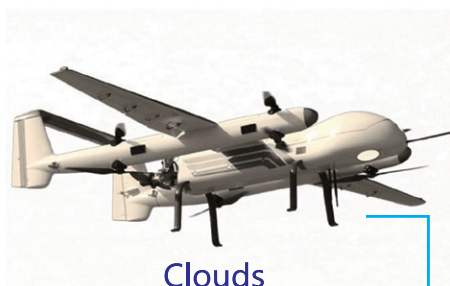
Clouds

Survey grade UAV LiDAR
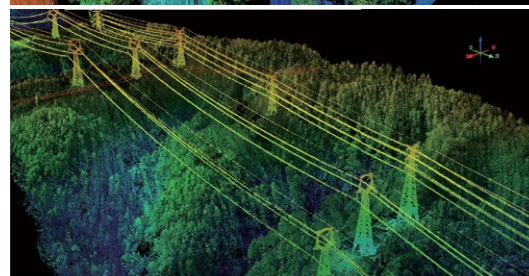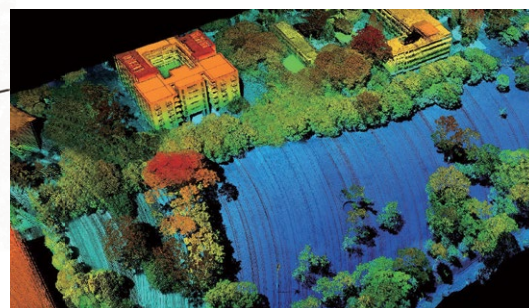
UAV performing a powerline inspection

UAVs and AVs fuel direct georeferencing boom

Applanix retains GNSS/IMU leadership

Taking advantage of travel to Toronto, Ontario, Canada for a meeting of the Council of the International Society for Photogrammetry and Remote Sensing, managing editor Stewart Walker Ubered to the suburbs, to visit Applanix, the acknowledged pioneer and lead player in GNSS/IMU technology for geospatial purposes. How were they doing? What changes have they made since we last visited in 2008[1]? Are they still first-in-industry? Here is what he found.

Applanix is housed in a conspicuous, modern building in Richmond Hill, Ontario, Canada, an area of light industry and professional activity amidst Toronto's northern suburbs. After quick words with sales manager Kevin Perkins, I was welcomed by marketing communications director Andrew Stott and director for airborne products and inertial technology Joe Hutton. Andrew joined Applanix in 2008, whereas Joe was one of the first employees when the firm was founded as Applied Analytics Corporation by Dr.

Blake Reid, Dr. Bruno Scherzinger and Eric Lithopolous in 1991. Applanix was acquired by Trimble Navigation in 2003. While its marketing materials reflect this and staff are quick to praise Trimble's role—as both a supplier of GNSS technology to Applanix and as a market for Applanix's position and orientation systems—a degree of independence has been maintained, so that the nimbleness, employee loyalty and sense of adventure often found in start-ups and small firms have not been diluted.

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1   Cheves, M., 2008. *Applanix: solutions for mobile mapping and positioning*, The American Surveyor, 5(8): 20-29, September.

BY DR. A STEWART **WALKER**

Applanix head office in Richmond Hill, Ontario, Canada

Applanix POS hardware

Joe Hutton, Director for Airborne Products

The company's efforts are divided into three main areas—airborne, marine and land. The third includes autonomous vehicle technology and indoor mapping solutions—Applanix produces the Trimble Indoor Mobile Mapping Solution, TIMMS. For these environments Applanix offers a number of specific, customized POS™ products including:

- POS LV for position and attitude (pitch, roll and heading) measurements for land vehicles. Applications include: mobile data collection, GIS and road surveying.
- POS MV measures the motion of multibeam echo sounders on marine vessels for seafloor mapping applications
- POS AV measures the position and attitude of airborne sensor platforms for aerial survey and mapping applications

- POSPac MMS post-processing software designed for the analysis of POS data
- Trimble AP GNSS-Inertial Board Set plus Inertial Measurement Unit (IMU): Applanix POS products for mobile mapping and positioning are available to original equipment manufacturers (OEMs) as AP Boardsets
- APX-UAV product line: single board GNSS-inertial solutions for direct georeferencing from UAVs
- Autonomy Development Platform: navigation solutions for autonomous vehicles research and development

Applanix continuously evolves, adapting to the needs of its partners to help orient their businesses for success. For nearly 30 years it has offered complete and customized solutions while championing the technology revolution that allows pinpoint positioning in any conditions.

Hutton focused immediately on the rapidly growing UAV-lidar market. *LIDAR Magazine* was privileged to receive a stream of his thoughts, which we present here, practically unexpurgated!

LIDAR Magazine (**LM**): Please give your thoughts on where Applanix is today in the airborne market, 28 years after the founding and 16 after the acquisition by Trimble.

Hutton: The hot topic is UAV-lidar. We supply RIEGL with all its mobile, airborne and UAV systems. We supply Teledyne Optech[2]. We have many new partners who are building very high-performance UAV-lidar solutions around our products. They're frequently using the RIEGL or Velodyne LiDAR scanners, sometimes FARO.

From my perspective, what is really interesting is how quickly the UAV-lidar market is picking up. People are realizing the high quality of the data they can get from the air on these lidar sensors. They're not doing big areas, just high-accuracy, high-resolution surveying that used to be done with

APX-20 UAV—Applanix has developed a lineup of APX boardsets for professional mapping from a UAV for any kind of application

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2 Our meeting took place prior to the unveiling of the CL-90 and CL-360 by Teledyne Optech.
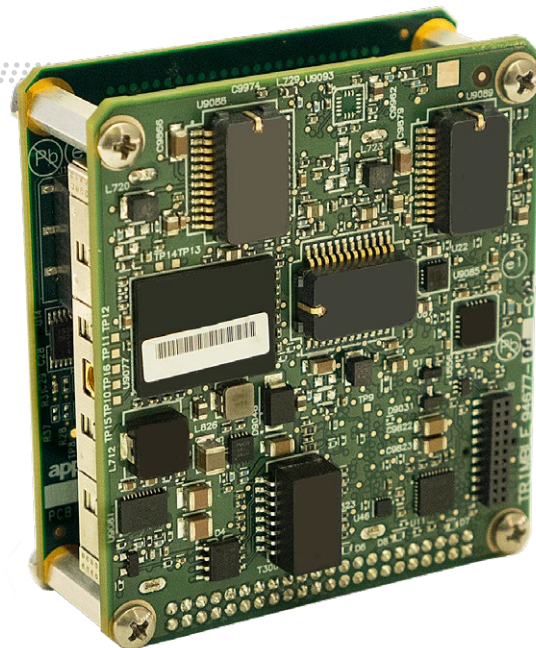
total stations or topographic static scanners—but they're doing it more efficiently. What's surprising to me too is that, yes, they are flying FAROs with millimeter resolution, but even the less accurate Velodynes are enjoying huge acceptance and uptake. You may have 5 cm of "snow", but these sensors are good enough, say, for power-line surveys and

you can see through the foliage. We're seeing all sorts of entrants, new lidars driven by the autonomous vehicle (AV) market—Quanergy, Cepton, DJI and so on. The target is AVs but you can produce interesting geospatial data very cost-effectively. We recognize that even these, on the UAV and at low altitudes, need very good georeferencing. So that continues to be our focus. That's why we came out with our APX product line four years ago. We saw the UAV market crystallizing and thought it was going to be all about photogrammetry, but now it's really turned out to be about lidar. You can actually get a point cloud while you're flying! Andrew and I attended the YellowScan user meeting [the week before this interview was conducted] and saw excellent lidar payloads based on Velodyne and RIEGL, with our product, nicely integrated and almost push-button.

Some competitors are now selling their own lidar solutions. What gives us a competitive edge is that we don't just sell a GNSS/IMU product, we sell a solution in the sense that we work with the OEM, understand what they're

UAV-lidar solution

trying to do, sit with them and hold their hand until that pixel, that point is at the correct location on the ground, exactly meeting the requirements. We can do this because we have the depth and the domain expertise to be able to understand georeferencing. YellowScan is the perfect example: we worked with them, developed the optimum solution, and it's been very successful. We don't leave a customer hanging.

LM: Do you know why that is?

Hutton: Historically, when Applanix was first bought by Trimble, we were starting to branch out into solutions, for example MMS. Then we decided that, as part of Trimble, we should return to our core,

The Trimble AP60 GNSS-Inertial System is an embedded GNSS-Inertial OEM board set plus Inertial Measurement Unit (IMU) in a compact form factor

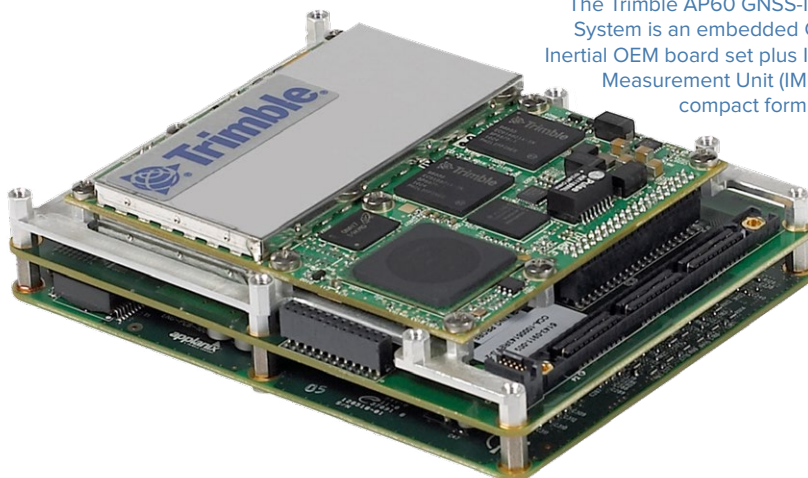

Trimble Indoor Mobile Mapping Solution, TIMMS

supplying the georeferencing solutions. TIMMS is an anomaly—the only real complete solution that we sell.

We don't even sell the DSS medium-format airborne camera any more, which came from TASC then Emerge. We still have the DSS technology, however, which we now sell through partners. We don't calibrate cameras and so on, we educate our partners on how to do it, how to integrate solutions. We supply some software, help them generate real-time orthos etc. Our job is to work with all the people trying to do aerial mapping and get our technology in there to help them do that.

We're not getting stale, because we realize the only way we can keep our clients happy and successful is to bring them all the new technology that comes to market. We invest heavily in R&D. Every IMU we use is custom-built by us or for us. We don't use anything off the shelf. We work with suppliers to develop and build a custom unit. That enables them to provide the performance we need at the right price points .

LM: How do you customize a MEMS IMU?

Hutton: At the board level the chips have a MEMS element and an ASIC (Application-Specific Integrated Circuit, an integrated circuit customized for a particular use). There's a little computer running on there that does certain things to the signals—signal processing and calibration—and that's the part we get customized. Even at the chip level, we'll be testing these things. We're saying, it's not meeting our requirements, what's going on here? We get them to correct things for us. We can do this at the chip level because we're part of Trimble. Applanix is the inertial center of excellence for Trimble, so our mandate is not just to develop products for our P&L but to take our GNSS/IMU technology to the rest of Trimble and to understand its inertial requirements. We've done joint developments with the agricultural and construction divisions. The agricultural division is a heavy user of inertial components on autopilots, steering systems and implements, because you need to know relative motion and orientation. They sell a massive number of products per year, which gives us enormous buying power if we can use common components.

This is why we are able to build our own IMUs at the board level, because we have economies of scale and enjoy competitive pricing. We go into the MEMS chip manufacturers and work with them to get the MEMS characteristics changed to Trimble's requirements. Typically, these manufacturers target automotive and industrial applications, but we see interesting characteristics and work with them. Once it gets to a higher performance level no longer suitable for the mass market, we usually find someone to build it for us. We test products from half a dozen to ten different suppliers a year, just to make sure we're on top of what's out there. Then we narrow it down. It typically takes about two years to bring a new product to market, to get it customized to the point where it meets our specifications. Our customer's expectation is a fresh product from us that gives better performance at good prices, or meets a performance goal that may not be there today.

That's on the inertial side. On the GNSS side, of course, we're part of Trimble. We are immersed heavily in GNSS development efforts, both software and hardware. We're part of the team that ensures that GNSS software and hardware are always being pushed forward to be the best—and we bring that into our products. What other capabilities do we see our customers needing? Our post-processing software, POSPac, is a big element of how you get the best accuracy for mapping applications. We have a dedicated team working on POSPac full-time. Our products are not just GNSS/IMU, we call it aided inertial or multi-sensor fusion: new technologies for aiding the inertial beyond GNSS. That includes optical and lidar aiding of the navigation solution

The Applanix autonomous vehicle technology development car

and what's driving that is the autonomy space. Our products are heavily used in industrial autonomy solutions, or off-road applications, and we're continuously seeing where we need to step it up in terms of solutions that are less GNSS-centric. GNSS is great, but when you lose lock or are indoors you need to constrain the position error growth

and you can't just use inertial as it drifts over time. We have developments in SLAM (simultaneous localization and mapping) and visual odometry (VO). All the technology we develop gets offered to our OEM customers, so if a customer has a lidar-based solution, we will say, here's some capabilities in POSPac to add VO or SLAM input.

POSPac MMS screenshot

LM: You're on top of it!

Hutton: We have to be. As we see inertial technology develop over time, the MEMS sensors get better. The holy grail is still a cheap, good gyro with very little drift and noise. There's a big jump right now from MEMS gyros at $10/$100 to those at $1000, and there's nothing in the middle. You want $1000 performance for $200. It'll get there. The AV market will push the development: you need a good MEMS gyro to bridge any outages even with map matching. The $10 and $100 gyros are not quite good enough. The $1000 gyros are good enough, closer to FOG performance if you know what you're doing, but are too expensive. They just haven't developed something in the middle because they haven't had a market for it before. But they can if they want. For avionics you can ask for more money, because quantities are lower, accuracy is higher, and certification is a must. Automotive doesn't need high accuracy for airbags and so on, but autonomous vehicles are different—safety of life is an issue, so they need higher accuracy and eventually certification. But the volumes are enormous. So now there's a market

to justify the development of a higher accuracy gyro at a lower cost. They have the designs for the avionics market, but AV is the market they need as the justification to do the work to bring the cost down. We use the full range from cheap MEMS gyros all the way to expensive FOGs with 500 m windings. Just as we've taken the automotive technology and customized it for higher performance, now, if the suppliers attack the AV market, we can take that and enhance it for our applications.

The current breed of automotive MEMS sensors has enabled us to get into the UAV market. You need less orientation accuracy, as the vectors to the ground are shorter, but you need low noise—even if you don't have the highest accuracy but you have a high-performance, low-noise lidar sensor. That's where we have focused and why we have different products. The APX-15 UAV is perfect for the Velodyne and similar sensors, because its error budget is within the noise level of the sensor—"in the snow"—whereas the APX-20 UAV can pull the best from the RIEGL VUX sensors. The APX-18 is the same as the APX-15 except that it

has two-antennae heading for hovering applications, for blimps, façade scanning and things like that. That's what differentiates us from our competitors, as well as the fact that we can explain to a customer how to do something—or why what they are doing won't work!
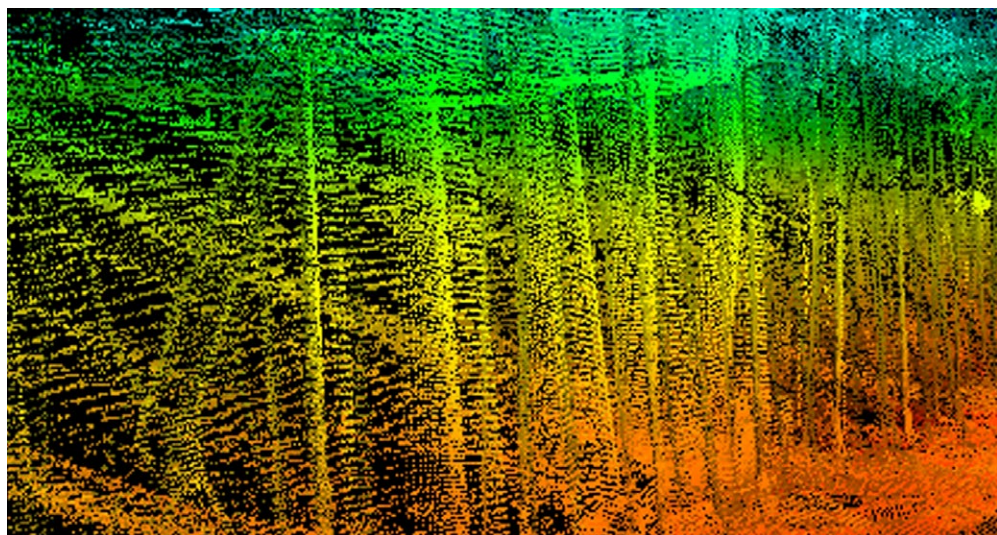
LM: Is that science finished, i.e. the problem is solved?

Hutton: The science is still developing—just think of the number of satellites in the sky now. It means you can do all kinds of interesting things that you couldn't in the past! One is the Post-Processed CenterPoint™ RTX service, which is really taking off for aerial mapping. Precise point positioning (PPP) is the overall terminology for that technology, which is basically doing carrier-phase differential GNSS positioning but without base stations. Centerpoint™ RTX is Trimble's version of PPP and Post-Processed Centerpoint™ RTX is the version embedded in POSPac. The concept of RTX is to have a network of stations around the world continuously monitoring everything that's in the sky, coming up with precise ephemeris data in real time. So you are not waiting for International GNSS Service (IGS) products. At this point you have corrected everything about the satellites and you have to correct every other part of the chain: calibrate the receivers, calibrate the antennae. All Trimble's base stations are the same, so there are no errors there, whereas with IGS it's all different. What error is left? The ambiguity, which is what you're solving for, plus atmospheric and tropospheric delays, plus receiver noise etc. Trimble has come up with a global model for the delays—that's the remaining thing to be solved for by the Trimble Kalman-filtering algorithms. If you can

transmit these corrections in real time over L-band or Internet, you can start to do centimeter-level positioning without base stations. Now, it takes some time to resolve the ambiguities: it's like the old days when you had to have float ambiguities and integer ambiguities, so with the standard global model it can take 15-20 minutes to converge to centimeter level. But they've just introduced Fast RTX by augmenting these stations so they have networks around the world with stations closer together. This allows local atmospheric models to be developed, including troposphere, and convergence as a result comes down to minutes.

They've rolled it out in different parts of the world and are using it in automotive applications, for example the General Motors Super Cruise autonomous driving system uses the Trimble RTX service.

So we've brought all that wonderful technology into POSPac. Applanix has access to that information and we can get rid of convergence delays since we are post-processing. It's a subscription, paid six-monthly or annually. You click a button, the software goes out to the web, grabs the corrections and does the forward-reverse processing to get centimeter-level positioning. If you have Fast RTX, which takes minutes to converge, you can use it on UAVs, which have short trajectories. That's where we are today in terms of the positioning state-of-the-art.

LM: Is there anything about a UAV that can compromise that?

Hutton: Yes, you need to be in an RTX Fast region with local atmospheric models. Mostly that's in Europe, but it's growing in US and Canada. If you're not in a Fast region, you may not have converged fully by the end of the trajectory. But you'll still be pretty good. If the trajectory is not long enough, the combined result won't be as accurate as with a longer trajectory. We recommend 15-20 minutes and you can even start it on the ground before you fly. We emphasize that you are solving for ambiguities and atmospheric delays, so you need clean data with few cycle slips. It's like the old days of differential GPS. You can do that if you have a good design. Our OEM clients have built these solutions and their data is very clean. It's very robust. All you need is an Internet connection. Over-the-air real-time RTX is also interesting: it's the same accuracy as post-processed RTX, but you don't get the forward-reverse ability to remove convergence. So the beginning of the flight will be less accurate than the end. However, people are starting to want real-time point clouds or they want the result when they land, but it doesn't need to be the final accuracy—so 10 cm is OK. For example, monitoring a construction site, if you can get a 3D model to compare to the day before and can provide that information quickly, it's good enough. The other example is rapid response or emergency response, for example landslides. We're at the point of creating accurate point clouds in real time and people are starting to look at the problems that can solve. How does it affect my decision process? Why do I need to wait? Waiting typically is about accuracy, but you are getting pretty good accuracy in real time.
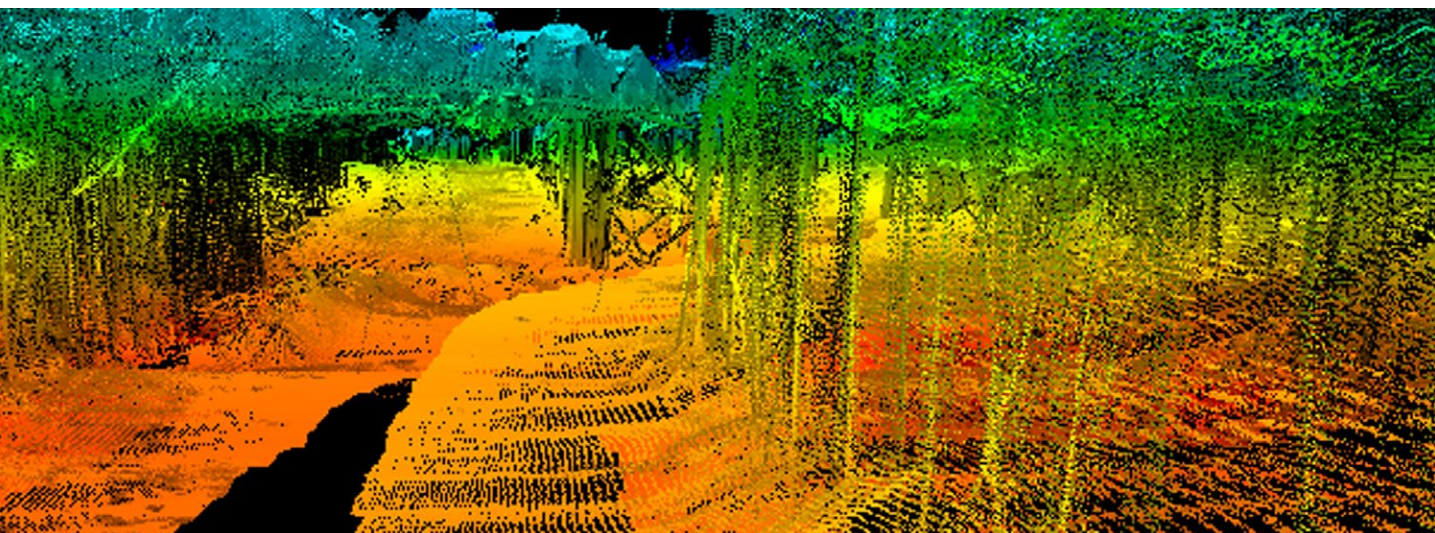
In photogrammetry you can't do traditional aerial triangulation in real time. We had to re-educate people in the UAV segment on direct georeferencing: everyone bought a camera and push-button UAV photogrammetry software and said they could map! We asked them about GCPs, processing times, accuracy. We had to explain direct georeferencing. We discovered that these UAV-photogrammetry software packages didn't import the exterior orientation (EO) georeferencing information correctly—they ignored the angles or de-weighted them so they were effectively ignored. You couldn't get a solution without point matching, yet you already had the accurate angles—that's frustrating. This is one of the reasons why we bundle our UAV products with Trimble UASMaster: it's a powerful UAV-photogrammetry software solution that properly implements direct georeferencing support! With a lidar sensor and a calibrated camera, you can create colorized point clouds and orthos without any triangulation process. If it's not a metric camera, or if you have mm GSD and cm GNSS accuracy, maybe triangulation will reduce the noise a bit, but typically people put only GNSS on and they solve every single time for camera and lens calibration and everything else, which constrains it in the air, and maybe constrains the average on the ground, yet it's a big Jello! You need to know what you're doing to get consistent accuracy. We train our photogrammetry customers: calibrate the camera, hold everything fixed, especially lens distortion, and if necessary just do a relative adjustment to refine any errors in EO, which is the traditional approach. It's very efficient, you don't need a lot of endlap and sidelap, and if you can't match points it doesn't matter, you still have EO! We've almost taken a step backward, but lidar is making us take a step forward. Lidar people ask, if I can create a point cloud to that level of accuracy without any adjustment, why can't I do the same with a camera? Well, you can, but you have to have the right kind of camera and software. However, I think the way lidar's going to go is automatic SLAM, another way of improving things. The ultimate solution is integrated sensor orientation for lidar and photogrammetry, where you use the best of everything and spit out the solution! We're close and it's a software matter. We're working on that type of technology for AVs and we'll bring it into the mapping segment as well. AVs are another real-time requirement, but post-processing can refine everything. We're releasing a new lidar QC module for POSPac[3], for example taking SLAM technology from the land side into the UAV segment—it uses SLAM, creates voxels from the lidar, does least-squares adjustment for boresight and, as an option, adjusts the trajectory and gets an adjusted SBET. The primary reason is to boresight the lidar automatically, but, also, if you're having problems with the trajectory, you can use the lidar to fix it and use that same trajectory with the camera. Lidar point cloud adjustment is much, much faster than aerial triangulation.

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3   This was released shortly after the interview.

LM: What about Trimble? The acquisition occurred some years ago, so there has been time to assess the benefits. Typically, acquisition gives the acquired company deeper pockets for development, but reduces innovation and nimbleness. On the other hand, it gives access by the acquired company to internal markets (other Trimble business areas), as well as a strong, global distribution network. To what extent is this true?

Hutton: That is all very true. Applanix is truly proud to be a Trimble company, since 2003. Applanix draws on Trimble's global network of experts and deep industry knowledge, while Trimble's related geospatial and autonomous technologies are complemented by Applanix's leading positioning, orientation, localization and perception systems. Together, customers have access to the most advanced solutions to collect, manage and analyze complex information faster and easier, making them more productive, efficient and profitable.

Applanix's industry leadership has always been predicated on our ability to innovate solutions for the evolving challenges of our partners. Trimble fully supports this. Our R&D teams are constantly pushing the limits of accuracy that can be obtained through almost any sensor in ever more challenging environments and developing software solutions that are practical, user-friendly but powerful enough to provide fast, efficient results. That's how we stay fresh—we strive through the people and a deep understanding of the business and the technologies—and R&D. Let me support my arguments by citing the words of three customers:

> " Applanix is a core market leader. Their AP boards are the main sensors used with the [SABRE-SCAN™] system, [and they] always deliver the same thing: highly accurate, dependable, repeatable results. Applanix has been very supportive: they're quick to respond to support our needs through the development process, are reactive to suggestions, and are always evolving their technology to become more compact, lightweight, and easy to use. "
>
> — *Paul Edge, CEO, SABRE Advanced 3D Surveying Systems*

> " Our team has been very happy with Applanix's products and support for the past nine years. The hardware, documentation and customer support are excellent. Applanix provides a well-designed, comprehensive solution. "
>
> — *David Hardy, geologist, Geological Survey Ireland*

> " Norsk Elektro Optikk has a very good relationship with Applanix. Both the sales team and the development team have been very helpful in our integration work. The development team has also included some features that we needed in the INS solution, and we are very grateful for that. "
>
> — *Trond Løke, Norsk Elektro Optikk.*

Bruno Scherzinger, co-founder and chief technology officer at Applanix Corporation

LM: What happened to Applanix's original principals?

Hutton: Blake Reid was a founder and president of Applanix before the Trimble purchase, and he stuck around for a while, went part-time, then retired around 2011. Dr. Bruno Scherzinger was also a founder and is currently our CTO. Bruno is also a Fellow in Trimble and takes a broader role. Our other founder Eric Lithopolous, who was instrumental in getting direct georeferencing accepted by the photogrammetric community, unfortunately passed away in 2014.

LM: We wanted to ask you, without going into deep mathematics, to show how Applanix's approach, honed through decades of research by talented scientists and engineers, gives it an advantage. We haven't done a deeply technical answer, but we have covered this.

Hutton: Yes, we've spoken about inertial, GNSS and our approach. The key point is that we like to play with things and try to help our customers. We understand the value to our customers and work with them to make them successful. For example, we're

Applanix – A History of Invention and Innovation

1991
Applied Analytics Corporation is born after Honeywell announces closure of ATC

1995
First **POS AV** test flight

2003
Applanix is acquired by Trimble

2009
Trimble AP series boardset of GNSS-Inertial OEM modules

2014
Direct Georeferencing for UAVs is introduced through the APX-15 UAV

2018
The Autonomous Development Platform is released

1994
First **POS LV** and **POS MV** delivered

1998
POS MV and **POS AV-DG** establish market dominance

2005
POS LV key factor in 1st and 2nd place finish at DARPA Urban Challenge

2010
Trimble Indoor Mobile Mapping Solution (**TIMMS**) is introduced

2016
POSPac 8 is released

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bringing the lidar QC tools to market because there's a definitive need. With the growth of lidar and integration, some tools are missing, such as easy-to-use boresighting. We did this with photogrammetry some years ago. We're doing the same thing with lidar. The SBET adjustment is similar to photogrammetry.

LM: There are now ASPRS or USGS standards for lidar QC, for example differences between strips.

Hutton: We focus on the best possible georeferencing. Our job is to solve for the boresighting, then, if we can use some of the lidar data to improve the trajectory, we will. Next come the point clouds. Our output is not point clouds, it is boresights and, if you want, adjusted trajectory—the georeferencing! We stop there, because then you're into the mapping part.

LM: What are your plans for the future in terms of markets? You've said that UAV is huge.

Hutton: It is, and so are AVs. We've developed the Autonomy Development Platform and are working on SLAM and VO capabilities for AVs as well. All the technology we've developed for UAV-lidar QC is applicable to AVs. Louis Nastro is heading up the effort and there's an article in *Autonomous Vehicle International*[4].

LM: How much of that is relevant for manned aircraft?

Hutton: With manned, it's not so critical, because the solutions are pretty much done. A lot of smart people

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4 Nastro, L., 2019. Point of view, *Autonomous Vehicle International*, October, 54-55. Reproduced at https://www.applanix.com/news/Auton-Vehicle-Intl_Nastro_Oct2019.pdf.

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figured this out a long time ago. You're open sky: you have perfect GNSS for positioning and FOG IMUs for orientation, so the lidar point clouds are excellent. You don't want to do adjustment on these massive point clouds, but with UAVs the point clouds are smaller, and you might be flying between buildings or under a bridge, yet you want to map it. There is also 360° lidar. That's where these tools are relevant. The same tools drive an industrial robot, inside or outside, automatically. We're taking technology from AVs and putting it into UAV-lidar. At some point, the same technology can be used to fly the UAVs if there's a market for that. In the future—judging by the direction UAVs are going—you'll say, here's my bridge, draw a little area on the computer, then the UAV will fly automatically, land, and there's your map.

LM: With advances like deep learning and artificial intelligence (AI) it will go further, for example identifying a bolt on a bridge as too rusty.

Hutton: Based on the sensor configuration—lidar and camera—it will know where that bridge is, how to fly it, it will go up, it will do collision avoidance, use SLAM, and, when it lands, there may be a brief pause, a push to the Cloud, and then you'll have the map. It will happen minutes later. Once you have the data, the accurate 3D model, the AI will do the inspection.

LM: Or compare the model with last year's? And then a human has to make the difficult decision whether to fix something or wait till it falls down!

Hutton: So you can fly with lidar and cameras, but there's still a manual aspect of flying. You'll be able to say, "I have a bridge at this location—go survey it for me". The technology is actually there. We're getting closer and closer. The same technology that's available for AVs today, industrial, on-road and off-road, is going into the UAVs, they'll work out how to find the bridge and survey it, given the approximate location. It has incredible eyes—cameras—and SLAM in real time, so it can work everything out after, perhaps, an initial pass.

LM: You'll still have a point cloud with millions of points?

Hutton: You'll be pushing it to the Cloud, where all that filtering and so on will be going on. You'll have a wonderful model for AI to work on. You have to think that AI will work as long as the data is collected consistently. We are working

in agriculture as well, where temporal analysis is very important. Having millimeter resolution data enables you to make very smart decisions about fertilizing, watering, harvesting or getting rid of waste. The enabler is radiometry with accurate georeferencing. We work with a group at Purdue University and there are some high-value crops which you can assess by area not even by height. You can tell based on the area, even from an ortho, and spectral characteristics, when to harvest. And we have customers talking about high-value crops such as strawberries, where you even have to look under the leaves. But whatever you do, you have to be sure you are looking at the same plant (in a temporal comparison). There are high-value crops where the waste in the harvest is up to 30%: if you can reduce this to 10%, it's worth millions of dollars. A crew will harvest everything regardless of whether it's ready, so the better you know whether it's ready, the better you can manage your business. It's enabled by accurate geolocation and high-resolution imagery that you can get only from a UAV. You're getting it from photogrammetry with a multispectral or NIR camera—for most of the applications all you need is an ortho. But we still need that centimeter level and we have to do it fast. We can't be running GCPs and triangulation. You need to calibrate the camera and it has to be stable. We show them that, if you calibrate the camera, we get 2-3 cm absolute accuracy on the orthos day after day. So you can starting thinking about how you can scale this.

LM: What about indoor? Is there more to do there?

Hutton: Always! We have TIMMS, where the challenge is that the number of applications is just enormous, from a 2D floor plan all the way up to a 3D model for security, situational awareness, emergency response, but that market is still conservative as well—"I can live with a 2D floor plan"—because they don't understand the value of better information. There are different aspects, from design to construction to life-cycle management. Building-management companies can pass on the survey costs to tenants! But they have to change the process, so at this point there's no incentive. That's commercial real estate. We did a lot of work on mapping buildings for first-responders, who relish situational awareness. The challenge is paying for it! Governments would have to mandate it and make the funds available. They don't need to establish the value—it's huge. You can save lives. You would have to legislate, for example to have it for new buildings.

LM: Joe, thank you very much indeed for these candid, informative insights into your company, its technologies and markets, and the trends it exemplifies.

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The Applanix facility

Joe took me on a whistletop tour of the plant, a buzzing hive of activity and technology. Finally, he rolled up a door through to the adjoining warehouse, which Applanix has taken over. Most of it was a games area for employees, including a ping pong table, a basketball court and a tennis court! Joe explained that Applanix competes with the high-tech titans for the very best graduates in subjects such

Employee break time

as electronics, electrical engineering and computer science, so it must offer top-drawer working conditions.

This area opened off the main facility, where we had seen R&D and testing areas, with lots of APX products. There are three inertial chips on an APX-15. The GNSS receiver is on the other side of the board. The APX-18 is 50% bigger. The APX-20 has two boards and an external IMU. They sell thousands of units per year, including sometimes hundreds to a single customer. This is a striking contrast to the high-end airborne and land systems, where annual sales would be in the hundreds. We saw the component design area and Joe explained that, when the design is final, Trimble can manufacture it in the required numbers, including offshore manufacture.

Applanix was coy about numbers, but Joe ventured that his part of Trimble has around 150 employees, of whom 120 are based in Richmond Hill. I said that this suggested annual sales of perhaps $45m, but Joe would not be drawn. He did add, however, that Kevin Perkins had exceeded $100m in accumulated sales over his career with Applanix.

Applanix tests numerous models of IMU, so that they understand the performance and potential of new units that come on the market. Joe showed me two vehicles in the facility, for testing GNSS/IMU systems and exploring AV technology. One was a medium-size sedan and the other, a van, the back of which was full of IMUs, one of which was the gold-standard, export-controlled Honeywell unit that Applanix uses to test all the others.

Endnote

Applanix has prospered, therefore, since the acquisition by Trimble, which provides it with GNSS components and services, as well as powerful channels for manufacturing, marketing and sales. Yet Applanix has retained certain elements more characteristic of a small company or start-up—top quality, talented and committed staff; healthy respect for R&D; progress through deep understanding of the technology, markets and customers' needs; and willingness to turn trends in markets and technologies to best advantage. R&D plus continuous testing of components enables it to stay fresh—nothing is stale in the APX world! The company is riding the transformation from selling limited numbers of top-performance systems for manned aircraft and MMS applications to selling large quantities that give appropriate performance at realistic price points into newer markets, especially UAV-lidar and AVs. It plans to remain the world-leader in GNSS/IMU expertise, while incorporating into its products sophisticated enhancements such as SLAM and OD. Not only will this offer more capabilities in the UAV-lidar and AV worlds, but the attractions of the indoor market loom large. Indeed, as the interview took place, the company was limbering up for its upcoming 2019 Workshop on Airborne Mapping and Surveying, a two-day educational and networking event, run jointly with camera supplier Phase One. While this reflects today's strong trend to user events as counterparts to professional conferences, it is better construed as a reflection on Applanix's success and its exuberant growth into the AV/UAV space. ▪

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

For example, I have seen some setups where the IMU was physically separated from the laser scanner by flexible carbon fiber rods: this design will never produce good data.

Figure 1 illustrates an area of three overlapping flight lines with significant misalignment. The grid spacing in the profile view is 10 cm. Note that the assessment tool is GeoCue's LP360 (True View Evo), using a line drape function that colorizes the drape lines by flight line. A line separation of about 20 cm is evident in the figure. While this appears as a vertical separation, it is caused by bore sight misalignment.

A second assessment that is critical to judging the consistency of lidar data is horizontal alignment. **Figure 2** is a cross section of several round hay bales, again with the profile shown as swath separated draped lines. Note the significant horizonal separation of about 40 cm between the cyan and green swath (most evident in the left side of the profile). This is again a result of bore sight angle misalignment. Note also the relatively good vertical alignment exhibited in the right side of the profile. This points out that just because you have good vertical alignment, don't expect this to carry over to horizontal.

Scale issues are more common in photogrammetric projects where an incorrect focal length is being held during processing. Scale can be assessed with either standard check points (assuming you have a method such as RTK to measure the points) or by using objects of known length in the scene (scale bars).

Finally, Network Accuracy is an assessment of how well the data set,
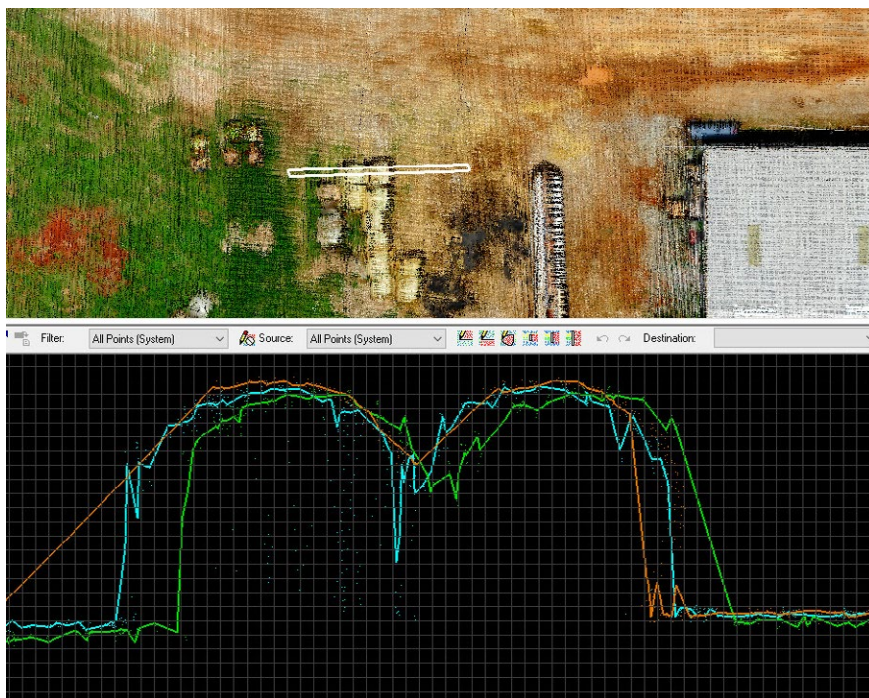
Figure 2: Horizontal Alignment

now internally consistent, match a particular datum. This assessment is invariably conducted using check points that have been "surveyed in" using some technique such as RTK. In an ideal world, you would always do this assessment using check points that are independent of the reference being used by the aerial platform. For example, use one base station for post-processing of the airborne sensor's positioning data and a second base station for surveying in the check points. Using this technique will uncover common blunders such as an incorrect base station height.

Not well developed at this time are standard techniques for assessing the network *horizontal* accuracy of lidar point clouds. For our own True View 3DiS, we use the imagery since it is locked, via body frame calibration, to

the lidar data. In laser scanners without firmly locked photogrammetric quality cameras, new techniques such as the generation of synthetic check points from linear feature intersections are needed. We will be looking at developing these tools this year.

The conclusion here is to not be satisfied with only a network vertical accuracy report for your lidar data. This will only reveal horizontal issues if the check points were placed on sloped surfaces. You really need to take a deeper dive. In other words, don't keep it between the ditches: look in the ditches! ℹ

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

Accuracy isn't One Dimensional

We have built dozens of True View 410 3D imaging Systems (3DiS) for sUAS over the past several months. With each unit, we do three manufacturing flight tests: an initial magnetic calibration flight, a full laser scanner/camera system calibration and finally a quality assessment flight. I wish I could convey how many hours and days we have spent perfecting our calibration processing and improving accuracy assessment: it has been an education!

We are building a repertoire of procedures that I feel are applicable to any drone camera/laser scanner system. The general areas of consideration are:

- Swath to swath alignment
- Local accuracy
- Network accuracy

Swath to swath misalignment is nearly always assessed as vertical separation between overlapping flight lines. For small area projects where the data were collected in a relatively short time span (e.g. several drone flights), these misalignments are dominated by two issues; a low quality inertial measurement unit (IMU) and/or mischaracterization of the angles between the IMU and the laser scanner (so-called "bore sight" angles). If you have a low accuracy IMU, you are out of luck (that money you saved on the front end will cause you no
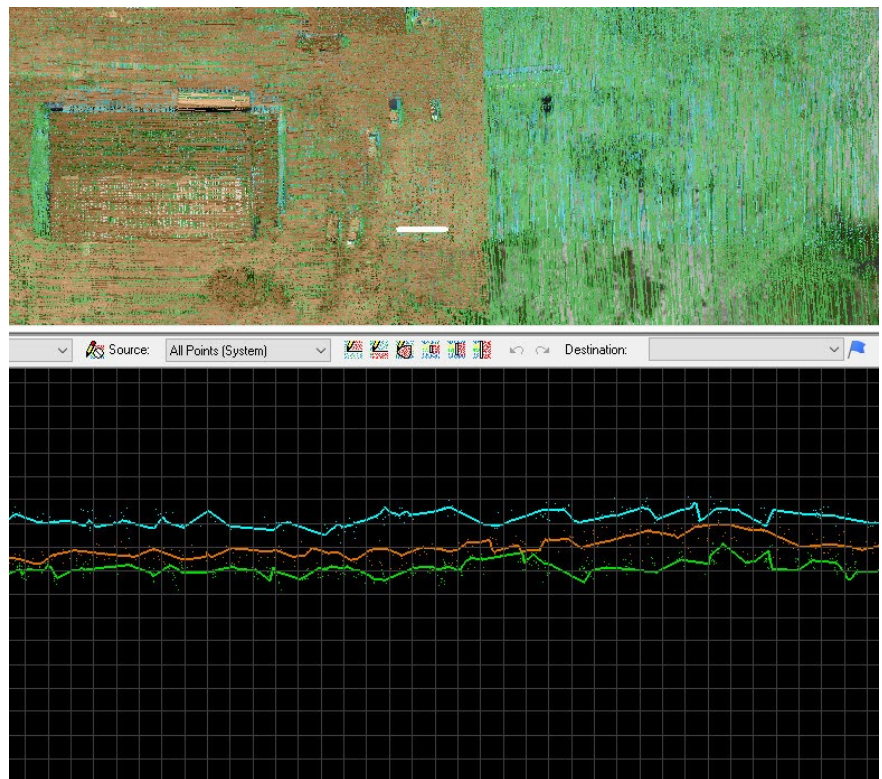
Figure 1: Vertical alignment assessment

> **"**...that money you saved on the front end will cause you no end of grief over the lifetime of the system!**"**

end of grief over the lifetime of the system!). Bore sight misalignment is easily corrected via a system calibration process. This can be tedious for multibeam systems such as Velodyne and Quanergy scanners since the process must be repeated for each beam. If you find that your system is not holding bore sight calibration from flight to flight, you may have a mechanical problem with the scanner.