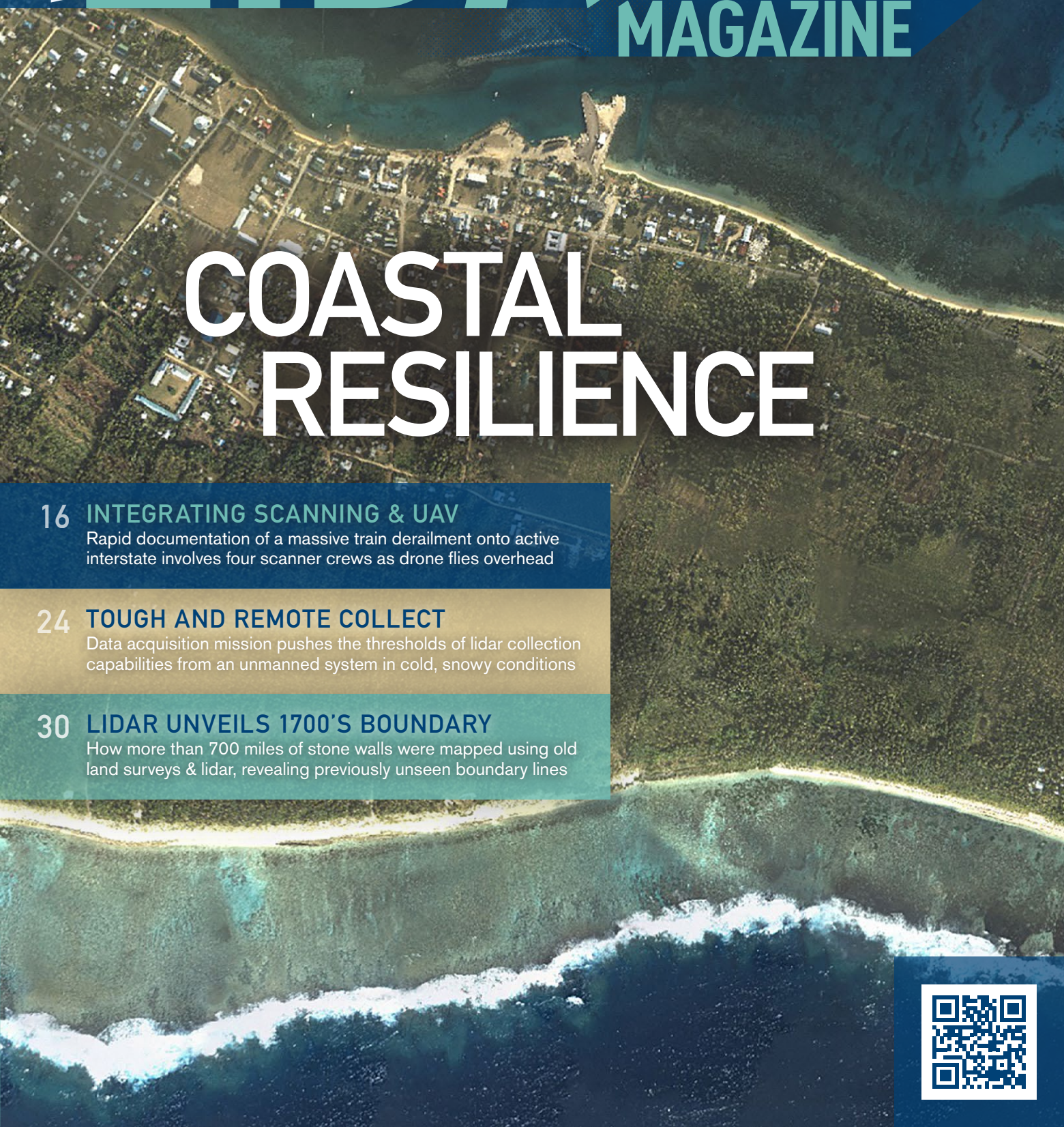
VOLUME 9 ISSUE 4

LIDAR MAGAZINE

JULY/AUGUST 2019



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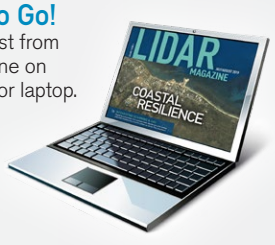

◀ ON THE COVER

Lidar can be used to accurately assess impervious surface area to determine the stormwater runoff generated by each residence or business parcel to mitigate and prepare for potential flooding. These assessments can be used to generate funding to support those efforts.
Image courtesy of the New Zealand Hydrographic Authority

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.

DR. A. STEWART WALKER

Enjoying the Energy

In the last issue, we reflected on the rambunctious nature of our industry and the likelihood that it will enjoy rapid growth over the next few years. Since then, we have been privileged to attend events and talk to movers and shakers, enjoying the energy, that lidar liveliness.

Hexagon once again laid on superb, informative events for the media at HxGN Live 2019 in Las Vegas, which attracted more than 3000 participants. The media group was given a tour of the exhibition area—the Zone—and your editor was seen attempting to hold a voice recorder, take a photo and write notes all at the same time. One-on-one interviews with Hexagon executives were arranged for us, but *LIDAR Magazine*'s session with Carl-Thomas Schneider, VP Business Development, Hexagon Geosystems, could not take place owing to a clash, so I submitted questions in writing. Carl-Thomas pressganged some colleagues to help, resulting in some intriguing insights—see page 6. While choosing between 500+ sessions was tormenting, it would have been unwise to miss the big plenary keynotes. Hexagon CEO Ola Rollén gave the event a thought-provoking opening entitled, "Can data save the world". Hexagon Geosystems president Jürgen Dold's keynote was as polished and compelling as ever and the audience was enraptured by the new BLK models he announced, BLK247 and BLK2GO. Given the success of the BLK360, these visually stunning products should sell widely, may well be disruptive and will feature in many projects in the near future. For all this modernity, he did not shy from reminding us that the earliest predecessor company of Hexagon, Kern had been founded 200 years ago. I took in a Taliesin West presentation and extracted the promise of an article! This is especially welcome given the recent news that Taliesin Wisconsin has become a UNESCO World Heritage Site. Next year Hexagon will focus on regional events in different cities round the world, but HxGN Live 2021 will return to Las Vegas—mark your calendars for 15-18 June.

Shortly thereafter, *LIDAR* Magazine accepted an invitation from GeoCue to attend the launch of its new True View product in Nashville, Tennessee. This was attended by around 40 GeoCue personnel, customers and invited experts. It was an unexpected surprise to be greeted at the door by Martin Flood, on his first day back at GeoCue after a spell at Teledyne Optech. GeoCue's reputation for undemonstrative, informative presentations suffered no harm as we heard from Lewis Graham and several of his colleagues, who were complemented by speakers from Vulcan Materials, a UAV user in the construction aggregates space, Applanix, RIEGL, Drone Rescue Systems (impressive parachute systems) and MFE Insurance Brokerage. True View is a combined lidar and imagery sensor designed for mounting on UAVs. Two GeoCue Mapping Cameras provide a 120° field of view,

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USIBD U.S. Institute of BUILDING DOCUMENTATION

TrueView

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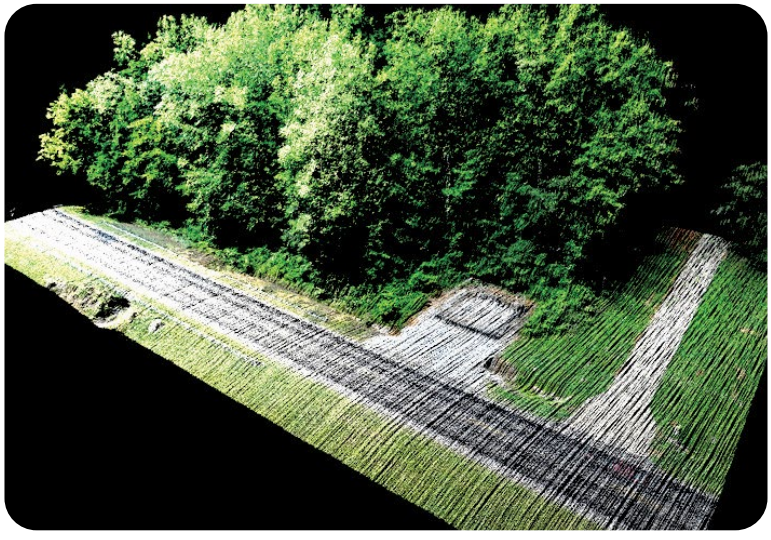
UAS LIDAR/Imagery Sensor Fusion



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

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coincident with the laser scanner track. The 25° oblique mounting ensures the sides of objects are imaged, allowing a true 3D colorization of all lidar points. The True View range will comprise several models, but the first, True View 410, has a Quanergy M8 Ultra laser scanner, which can fly at up to 100 m and provides three returns. An Applanix APX GNSS/IMU is incorporated, which comes with Applanix software and the option to subscribe to Trimble's positioning services. Full details can be found on page 44, but we must not end without mentioning the onboard processing on a Google® Coral TensorFlow Processing Unit, GeoCue's own True View Evo post-processing software and a choice of purchase and subscription options. Clearly, True View has been meticulously designed by a company with extensive experience of both integration and the provision of services.

Less than two weeks later, *LIDAR Magazine*'s presence at the annual Esri jamboree in San Diego began with the Imagery Summit pre-conference event, which attracted more than 200 participants to learn about Esri's latest developments on the imagery side. Esri's Director of Global Remote Sensing and Imagery, Richard Cooke, opened the meeting and explained how Esri is tuning its structure to give even better products and support to its imagery customers. The main International User Conference ran from Monday to Friday as usual and this year attracted a record 18,587 registrants. In addition, Esri had more than 26,652 unique viewers of the plenary livestream and stated that a combined number of 45,239 people participated in this year's conference. The big plenary, beautifully orchestrated and well presented by Jack Dangermond together with numerous colleagues and guests, was as awe inspiring as ever. *LIDAR Magazine* liked a presentation by the City of Pasadena, which is using GIS to enormous advantage in multiple municipal departments, but the show was stolen by three students from schools in Lurgan, Northern Ireland, a town hard hit by The Troubles. The students were introduced by a policeman from Lurgan, then spoke about their use of Esri products to conduct a field survey and analyze the results, about comfort levels of people in Lurgan at different sites and different times of day. The session was concluded with brief words from Lurgan teachers and *LIDAR Magazine* was by no means the only lachrymose attendee. Like Hexagon, Esri laid on a fabulous program for the gentlepersons of the press, including guided tours of the exhibition and the map gallery as well as small-group access to senior Esri executives and to Jack Dangermond together with two of his VIP guests, Drs. Jane Goodall, DBE, and E O Wilson.

Esri has run user conferences since the beginning of the 1980s, when it was changing from a consultancy to a software supplier. With its enormous International User Conference coming hot on the heels of HxGN Live, it's worth taking a moment to reflect on the role of these meetings, run by private companies rather than professional societies or conference organizers. We have spoken about Trimble's biennial Dimensions event in these pages too—and there are many others. Your editor was involved in running such meetings during his career on the supplier side, but his first effort, the UK Kern DSR user meeting in York, England, in 1987, with 13 customers, was smaller! Attendance at the Esri event nudges Intergeo into second place. It's eight times as big as an ISPRS Congress more than twelve times as big as Geo Week, and more than double ACSM-ASPRS in its heyday 30 years ago. These user meetings not only present the latest technologies, they encourage and publicize imaginative and challenging applications. Many speakers at these meetings do not publish in academic journals, but they are instrumental in advancing the technology and its uses. Nevertheless, many academics take advantage of this sort of platform. User conferences are more brash, perhaps, than academic conferences, yet they are a broader church. They complement the academic events, so the two together provide effective vehicles for reporting and fomenting developments in our lidar world.

In an earlier editorial, I warned that Système International d'Unités (SI) definitions of fundamental units of measurement were about to change. They have, and on 20 May 2019, the kilogram was redefined[1]. It is no longer the mass of a chunk of metal inside a series of bell jars in a vault near Paris, but is now defined in terms of the Planck constant which has been measured with extraordinary precision in recent years: its agreed value is $6.626{,}070{,}15 \times 10^{-34}$ kg m^2 s^{-1}. Remember that the meter and the second have already been defined. Readers may wish to incorporate the new definition when considering lidar payloads for UAVs.

A. Stewart Walker // Managing Editor

1 Anon, 2019. Perfectly constant, *The Economist*, 431(9143): 75, 18 May.

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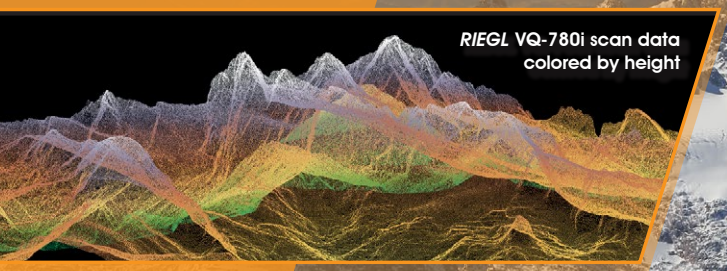

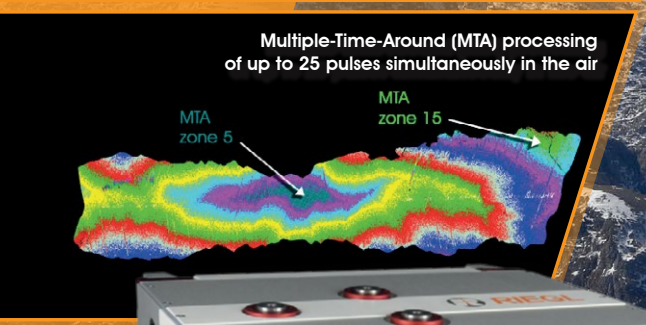

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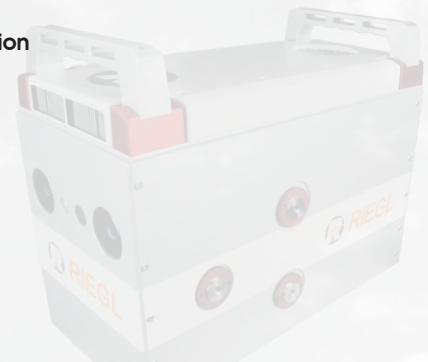

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HxGN Live 2019

During HxGN Live, held this past June in Las Vegas, Nevada, Managing Editor Stewart Walker caught up with Carl-Thomas Schneider, VP Business Development, Hexagon Geosystems, and several other Hexagon team members for a quick discussion of where things stand and how they came to be:

Q **LIDAR Magazine (Dr. Stewart Walker):** You began in surveying and geodesy, with degrees from Hannover and Braunschweig. Had Wilfried Wester-Ebbinghaus passed on when you attended the latter? Then you went to Volkswagen?

Carl-Thomas Schneider: After finishing my Diploma at the University of Hannover, I continued as a postgraduate at the Volkswagen R&D department and received my PhD degree in 1990 from the Technical University of Braunschweig. Prof. Wester-Ebbinghaus moved from the University of Hannover University to the Technical University of Braunschweig in 1986.

Q LM: You became joint CEO of AICON 3D Systems, which Hexagon acquired in 2016. Please tell me more about that.

I founded AICON 3D Systems in 1990 and established the company as a global provider of camera-based 3D metrology systems for quality control, testing and reverse engineering in various industries. When we joined Hexagon in 2016, AICON had 150 employees and subsidiaries in Asia and North America.

Q How did this acquisition fit within Hexagon's overall strategy?

The acquisition strongly supported Hexagon's Manufacturing Intelligence division. Please see here for further information: https://bit.ly/2YyxqrC

Q How is Hexagon doing? How do this year's results compare to last year's? It seems that the long-term growth objectives are being met, with both gross revenue and earnings (EBITA etc.) increasing year by year, and that the company has strong long-term plans. Is any of the divisions proving to be a cause for concern?

Hexagon has steadily increased its EBIT and is on track to continue do so. Q1 results were released in May and almost all figures were on the increase (for more information, please see here: https://bit.ly/331925z). Our diversified portfolio enables us to offset downward turns in any one division with another throughout the year.

Q How is business development organized across Hexagon, which seems to be quite a complex organization?

Again, we have a diversified portfolio across many industry sectors. We also have an active and healthy M&A strategy to fill any gaps we identify across the market. We're consistently on the lookout for new opportunities and markets, such as the Leica BLK247 we just released at HxGN Live that opens doors for us to the surveillance sector.

Q What is Hexagon's strategy towards acquisitions? Is there a size ceiling or floor? Is the strategy based on innovative technologies, gaps in the Hexagon product palette, new verticals, or what? How do you tackle the make-or-buy quandary in these cases?

Where there is a gap in expertise, we acquire. When we want to enter a new market, we partner or perhaps put our M&A strategy into effect. Our course of action is determined on a case-by-case basis, carefully examining all the factors of the particular scenario to make the most informed decision.

Q Our magazine, of course, is involved in lidar, including airborne, MMS, TLS and, increasingly, automotive. I was Leica's product director on the airborne side almost 20 years ago! Hexagon has products in all four of these areas, isn't that correct? Do you think it has a big play in automotive?

Yes, we do operate in all of these areas and quite a few more. Our acquisition of AutonomouStuff has brought us into the autonomous vehicle market (see here for more information: https://bit.ly/2OwESUL), where we

see a strong match with our lidar solutions in this area. Furthermore, our mobile mapping portfolio also opens doors into automotive as it is vehicle-agnostic.

Q In a recently published research report, Global Marketing Insights not only forecast massive CAGRs for the lidar market and various segments within it in the 2019-25 timeframe, but said that there would be parternships, mergers, acquisitions and so on as firms try to position themselves to take full advantage of the growth. Do you agree with this and what does it mean for Hexagon? Maybe this would be a good point at which to comment on the relationship with Matterport, which I heard about in the context of the survey of Frank Lloyd Wrights' Taliesin West near Phoenix, Arizona.

Brian Smith, emerging technologies product manager at Multivista and construction technologist at Leica Geosystems: At Hexagon, we collaborate with strategic partners to strengthen our portfolio and fill in gaps. The partnership between the Frank Lloyd Wright Foundation (FLWF), Leica Geosystems and Multivista, for instance, was formed in 2018 (more details are available here: https://franklloydwright.org/3dlab/about/ and https://bit.ly/2GE2iB5). This summer, Leica Geosystems will be conducting data capture for Taliesin Wisconsin. This will be another unique test of technology and pioneering new data capture processes for preservation and architecture. Our collaboration with Matterport is around the technology of the Leica BLK360 and is outside our initiative with FLWF. These partnerships are just a couple of many examples of where we've found opportunities to branch into new markets and close gaps in our offerings.

Q Last year Hexagon announced huge performance improvements in its bathymetric and topobathymetric lidar sensors. These were dramatic—have you seen a corresponding improvement in your placement within the market?

Anders Ekelund, vice president of airborne bathymetric lidar at Hexagon's Geosystems division: We are a leader in bathymetric lidar with our Chiroptera and HawkEye airborne sensors. The market is still emerging, but, during the last years, we have seen a steady growth, mainly caused by both an increasing number of hydrographic offices which start to use the technology for shallow water charting, and also an increasing number of mapping organizations which start to use the data for flooding analysis in rivers. We expect to see a continued growth, similar to the development of airborne topographic lidar a number of years ago.

Q Although I represent LIDAR Magazine, I am a photogrammetrist by training. Would you like to say something about what's going on in Hexagon on the photogrammetric side?

My former company AICON 3D Systems is now part of Hexagon Manufacturing Intelligence and integrated in the Portable Product Line (together with measuring arms and laser tracker). AICON is continuously developing photogrammetric systems for close range industrial applications. Just recently a high-end photogrammetric camera, the C1, has been released for high accuracy demanding industrial applications.

Q The Hexagon Content Program or Service, as I saw it called today, is leading-edge on technology but also on business model. Would you like to say something about this, including the engagements with customers and partners?

Paul Smith, product strategist, HxGN Content Program: The HxGN Content Program, providing unparalleled quality airborne imagery and lidar, is our answer to the new data economy. We're seeing our customers using it innovatively, including coupled with machine learning to automatically detect roadway types and parking for autonomous navigation, supporting insurance industry partners for post-disaster recovery, and helping field crews to be safer during on-site inspections.

Q Any thoughts on drones?

Valentin Fuchs, UAV business director at Leica Geosystems: We see UAV as an additional technology sensor part of the tool chain for professionals requiring accurate geospatial 3D data, such as surveyors, contractors and so on. Thanks to photogrammetry solution, it is becoming very simple for clients to get accurate 3D data from a larger area than with traditional methods - it opens new business opportunities. Combining UAV data with other Reality Capture sensors like Laser Scanning or Mobile Mapping systems, allows to get a complete Digital Twin of objects which has not be able before. With Leica Aibot solution and the Leica software ecosystem, users are able to get high accurate survey type accurate data to trust. The more the data can be trusted, the better actions can be derived in Surveying or Construction or other industries.

Thank you for your time and thanks to Penny Boviatsou for setting up our session(s).

Esri Imagery Summit and User Conference

Kyle Talbot, Solution Engineer, Esri, presents the "Imagery Top Ten" on Sunday, July 7th at the Esri Imagery Summit

To see what others can't...

Every summer, close to 20,000 geospatial professionals descend upon San Diego to gather inspiration from the preeminent GIS software developer, Esri. The firm now supports an astounding 350,000+ organizations globally*.

An annual treat tucked into conference tote bags is the "Esri Map Book", a sampling of work from customers around the globe. In the preface of this year's edition (#34), Esri founder Jack Dangermond congratulates those selected for inclusion, explaining that their work "illustrates how Spatial thinking is helping professionals from many fields make better decisions and then act on them in a new way".

These days, when discussing sensor or imagery integration trends, sooner or later, one is bound to encounter the "weaving" analogy. Considering individual data sources as thread(s), GIS software operates like a loom, weaving a multitude of strands into a complex pattern that affords users the "big picture". While this is great for researching known patterns and trends, it has become increasingly valuable in identifying previously unknown patterns and other root causes. Ongoing advancements in cloud computing and machine learning promise an entirely new realm of possibilities in this regard.

You can't fix what you can't see...

Esri places considerable emphasis on developing (data) sources. In this vein, the Imagery Summit was formed, creating a forum to discuss the satellite imaging and remote sensing ecosystem, an area that produces what many would consider to be a "main thread".

Here are some of this year's "Notable quotables", comments shared by panelists at the 2019 Imagery Summit:

The global sensing revolution

"It's not just an observational revolution, it's a global sensing revolution. We have drones going underwater, satellites, cell phones in our pockets with increasing ranges of sensor data, and it's our job to figure out how to utilize all of that and make it interoperable as best we can. There's a lot of misconceptions out there about the different use cases that are revalent within different data sets... People need to understand and better specify where imagery matches the problem."

—Will Marshall, Planet

"Lidar has been a game changer for NRCS (National Resources Conservation Service) for conservation planning and design. Historically, we relied on mixed use topographic maps for a lot of our planning work; now, thanks to lidar, we can generate really accurate one and two-foot contours in some of the areas where they're doing land leveling and trying to control water via water management systems, both for controlling runoff for nutrients but also for keeping the water in place for crops. The engineering community has really embraced this (lidar). At first, there was some reluctance to use it because it came from a fixed wing aircraft—now that they've seen it, and have taken their own methods to verify it, the acceptance has really skyrocketed."

—Steven Nechero, NRCS, a division of USDA

The digital revolution

"The digital revolution within our field office from hard copy maps in every field office, every county across the US, taking analog imagery and turning that into ortho products, and now the revolution with the 3DEP program, promising lidar, wall to wall for the lower 48 states, farmers and ranchers have access to this information not just for farm production but for conservation efforts such as trying to keep soil erosion in check, monitoring the (effect) on waterways, different wildlife habitats, it's an exciting time to see how much the data is being integrated and how the end user community has been empowered."

—Steven Nechero, NRCS, a division of USDA

Machine learning

"While machine learning is overhyped in some areas, in certain classes of problems, like feature identification from images, such as (identifying) a ship, tree, road or house, that sort of thing has been largely solved—previously, this required teams of analysts and PhD's in GIS to get this sort of information out— interns can now automate roads and buildings in minutes. This brings the use of imaging to a far larger group of people than it once was...."

—Will Marshall, Planet

Notable Trends

"There's an 800 lb. gorilla in the room, in the accuracy and precision of datasets—there's a huge amount of legacy data that's tied to imagery—when we move that data around, I'm talking spatial accuracy, you have to go back and correct the topology and the vectors and analyze them. Deep learning is going to require some deep cleaning..."

—Robert White, MAPPS

"I'm seeing imaging and GIS convergence, govt and private sector convergence, the proliferation of data and the ability to extract information from it at scale using machine learning—people are seeing that we can apply this, that it's not just a demo, that we can actually effect the mission."

—Tony Frazier, MAXAR

Unveiling of ArcGIS Excalibur, a new image exploitation tool

Users closest to the front lines have described a transition to an "imagery first reality" in which imagery sits atop GIS systems and principles; much of this has to do with the imagery itself, considering the quality, portability and integration capability of today's datasets. Esri's new extension, "ArcGIS Excalibur", serves to integrate image exploitation. Esri explained:

"Part of the Esri Geospatial Cloud, ArcGIS Excalibur is a project-based imagery application that modernizes and enhances image-based workflows through intuitive experiences." Users may "view drone, aircraft, or satellite imagery as collected along with authoritative geospatial contextual and operational layers; assign and manage imagery exploitation tasks across the organization; compile, publish, share, and disseminate dynamic information products to consumers and devices in multiple formats."

**User information supplied by Esri.*

Lidar can be used to accurately assess impervious surface area to determine the stormwater runoff generated by each residence or business parcel to mitigate and prepare for potential flooding. These assessments can be used to generate funding to support those efforts.
Courtesy of the New Zealand Hydrographic Authority

Lidar Data Supports Coastal Resilience Planning and Funding

Coastal Communities Require Highly Accurate Elevation Data for Storm-Surge Modeling and Stormwater Initiatives

Coastal resilience is defined by the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service as proactively building a community's capacity to "bounce back" from hazardous events such as hurricanes, coastal storms and flooding before a disaster takes place. For a state like Florida, whose geography, elevation and topography make it vulnerable to storm surges, susceptible to hurricanes and predisposed to sinkholes, coastal resilience is not an option—it's a necessity.

NOAA's Office for Coastal Management reports that roughly 40% of the U.S. population, or 126 million people, live in coastal counties, which produce more than $8.3 trillion in goods and services, account for 56 million jobs and pay $3.4 trillion in wages.

In Florida, 14.4 million of the state's 21.6 million population—or nearly 70% —live within its 8,436 miles of coastal counties. From 1980-2018, the Sunshine State also sustained 53 separate billion-dollar weather and climate disasters. In March 2019, NOAA reported that the

BY MIKE **ZOLTEK** AND SAM **MOFFAT**

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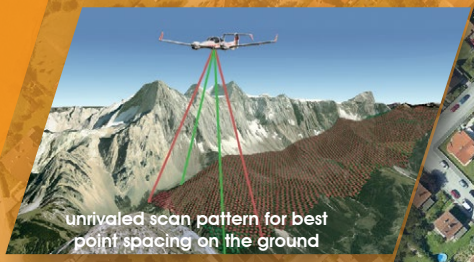
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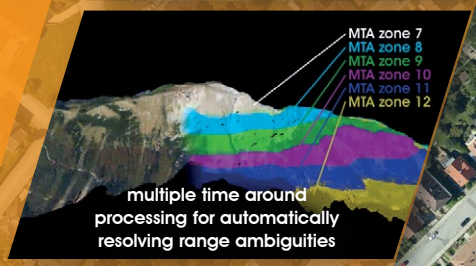

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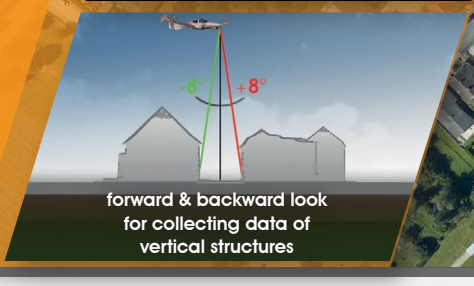

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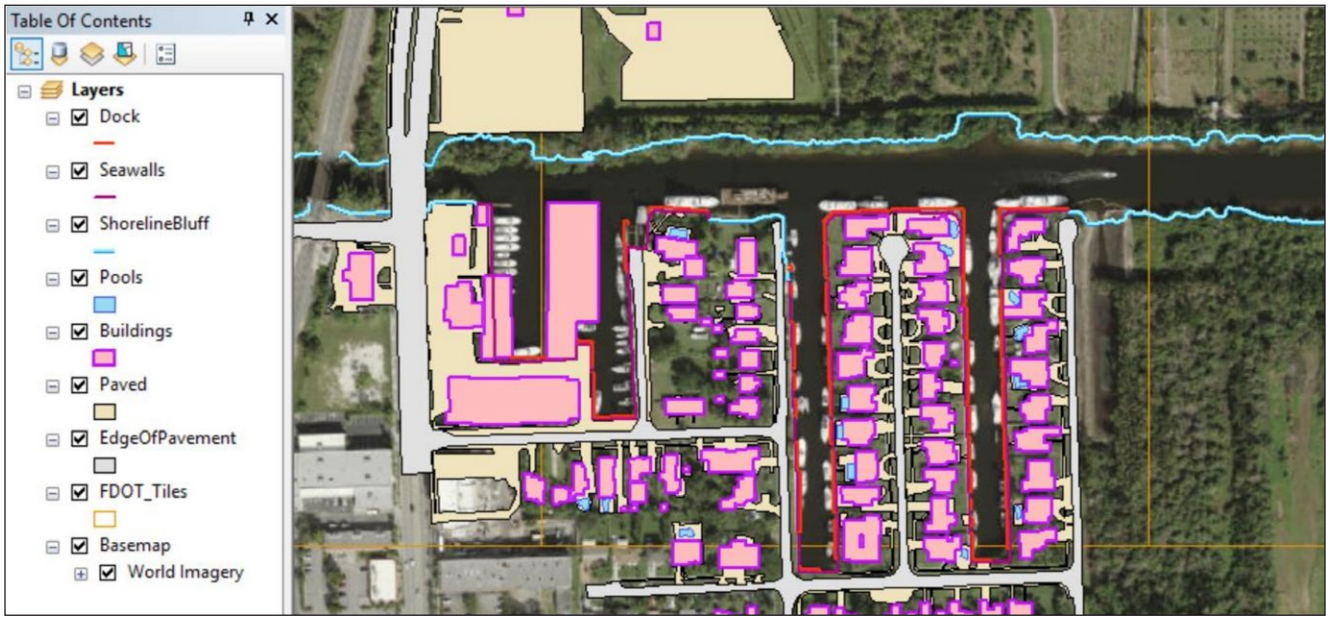

This resilience bundle of 3D features was mapped utilizing Woolpert's trademarked remote sensing solution.
Courtesy of Woolpert.

Atlantic Ocean remains in a "high-activity" era of increased hurricane activity, with a propensity for more, stronger and longer-lasting storms. Historically, these high-activity periods last 25-40 years.

In heavily populated Miami, the highest tides of the year, called "king tides," annually flood roads and disrupt life in low-lying areas of the South Florida community. The federally conducted Third National Climate Assessment pinpointed the Tampa Bay area, another large population center, as particularly vulnerable to rising sea levels. Broward County's coastal areas are part of a Federal Emergency Management Agency multiyear study on flooding caused by coastal storms.

Given these statistics, the need for coastal resilience planning is repeatedly and unquestionably clear; fortunately, the route to support this need is equally apparent. Up-to-date, highly accurate lidar data and orthoimagery provide the information needed for creating storm-surge models to adequately prepare for disaster in the coastal environment. This elevation data leads to the precise delineation of coastal lands, roads and infrastructure, and enables officials to identify areas most vulnerable to inundation and destruction. The application of this data can help communities most effectively weather natural disasters and can be used to generate funding to support these vital efforts.

Lidar collections and applications throughout Florida

Highly accurate lidar data is currently being collected across the country and around the world through multiple efforts. In Florida in 2018, federal partner agencies contracted for the acquisition and processing of Quality Level 1 (QL1) lidar data across 34,873 square miles.

The QL1 data will be used to create the most accurate surface model the state has ever had. In addition to hundreds of statewide initiatives, this project will be available to help federal, state and local agencies to effectively address disaster response and flood-related issues, asset management, impervious surface mapping for storm-water management, property valuation, risk management and other mapping needs specific to the wide range of topographies across the country.

The Florida Division of Emergency Management (FDEM) has long valued the collection and application of lidar data and high-resolution imagery in its disaster preparedness, response and recovery efforts. The organization provides links to several internet-accessible lidar portals on its website at floridadisaster.org and works with the Florida Department of Transportation (FDOT) and representatives from all five Florida Water Management Districts to support the collection and application of this data.

In addition, FDOT contracts for the collection of lidar data and supporting imagery to help determine the infrastructure most in need of strengthening prior to disaster and to determine the safest evacuation and emergency response routes post-disaster. The data can identify which roads and bridges will be accessible at various flood surge levels and how regions should be prioritized, appropriately updating emergency preparedness and response plans.

The accurate maps and models generated by geospatial data have routinely proved their value, especially in the wake of recent Florida disasters. In September 2017, for instance, when Hurricane Irma hit the state, Woolpert collected immediate post-storm orthoimagery contracted through its five-year statewide contract with FDOT, as well as through Miami-Dade County, to document damage assessment and current flood conditions. The information, aggregated with data from NOAA and Google, was shared and incorporated into rescue and recovery efforts within hours of the event for anyone affected by the storm.

Counties and groups band together to coordinate resilience planning

On the federal level, NOAA's Digital Coast aggregates the input of its member partners to provide public safety, emergency response and economic resources to coastal communities through imagery, data, tools and training.

In Florida, the need for coastal resilience planning is so critical to its southern and eastern coastal communities that, in 2010, the counties of Broward, Miami-Dade, Monroe and Palm Beach formed an alliance called the Southeast Florida Regional Climate Change Compact to work together to coordinate mitigation and to respond across county lines. The Compact works with federal, state, regional, municipal, nonprofit, academic and private sector partners, and represents "one of the nation's leading examples of regional-scale climate action"[1] through workshops, summits and programs. The Compact discusses lidar and imagery applications and incorporates data from its counties' work with the U.S. Geological Survey (USGS) to develop hydrologic modeling, illustrating the impact of sea level rise and extreme

1 southeastfloridaclimatecompact.org/about-us/what-is-the-compact

When Hurricane Irma hit Florida in 2017, Woolpert collected immediate post-storm orthoimagery contracted through its five-year statewide contract with the Florida Department of Transportation, as well as through Miami-Dade County, to document damage assessment and current flood conditions.

Courtesy of Woolpert.

flooding on the region. It then shares those models with other jurisdictions.

Florida's Office of Resilience and Coastal Protection, operating within the Florida Department of Environmental Protection (FDEP), was also created to help coastal communities prepare for the impact they may face from rising sea levels caused by hurricanes, storms or flooding. FDEP administers the Florida Resilient Coastlines Program, which is an initiative to allocate millions of dollars in grants to local governments to assist them with coastal resilience projects. Communities awarded funds for coastal resiliency projects utilize geospatial data to set the foundation for effective stormwater planning, withstanding disaster and adapting to changing sea levels.

Lidar's role in generating funding for coastal resilience and stormwater utilities

Municipalities across the U.S. measure their impervious surface areas to determine the stormwater runoff generated by each residence or business parcel to mitigate and prepare for potential flooding. If this data is outdated or insufficient, it can make an already bad situation much more devastating. For example, studies done after Hurricane Harvey, a Category 4 storm that killed 68 and caused $125 billion in damage in Houston, Texas, in 2017, directly fault the city's growth and increasing miles of impervious surfaces for the subsequent flooding. Princeton University and University of Iowa researchers estimated Houston's risk for extreme flooding during the hurricane was 21 times greater because of the city's development.

In addition to saving lives, these assessments also can support stormwater utilities by charging a fee based on the amount of impervious surface created by development to help fund the operation, construction and management of stormwater services. These measurements historically have been calculated using a manual digitization method that produces a standard, average rate. It has proved, however, to be labor intensive and prone to human error, making the data inconsistent and unreliable and the results subject to debate.

"Studies done after Hurricane Harvey directly fault the city's growth and increasing miles of impervious surfaces for the subsequent flooding."

Florida is perennially among the fastest growing states, and therefore has seen consistent and exponential growth in its impervious surface area. The state has used manual digitization of impervious surface method for years, but independent reviews of that system show a stark need for improvement. On its 2016 Report Card for America's Infrastructure, the American Society of Civil Engineers gave Florida a stormwater grade of "D." At the same time, the Florida Stormwater Association's 2016 Stormwater Utility Report found the state's capital improvement needs for stormwater management to be $1.1 billion through 2019.

To improve this process, better manage stormwater and mitigate subsequent flooding, a more accurate assessment system of impervious surface area is required. That's where lidar comes in. By using a semi-automated feature extraction method incorporating both digital orthoimagery and lidar, precise impervious surface measurements can be collected that not only support a fair and equitable stormwater fee structure, but most effectively prepare communities for disaster—whether they are in the Midwest, the mountains or on the coast.

Although we can't stop natural disasters from occurring, we can and should use proven geospatial technology to protect ourselves.

Mike Zoltek, PSM, CP, CFedS, GISP, is a senior project manager in Woolpert's Government Solutions market. A licensed land surveyor in Florida for over 22 years, the University of Florida graduate is a licensed professional surveyor in 26 states, an American Society for Photogrammetry and Remote Sensing (ASPRS) Certified Photogrammetrist, a Certified Federal Surveyor and a geographic information systems (GIS) professional with nearly 30 years of experience in the geospatial field. Zoltek is on Florida's State Board of Professional Surveyors and Mappers and the ASPRS Florida Region Board of Directors, and was recently selected to chair the ASPRS Evaluation for Certification Committee.

Sam Moffat, GISP, is a geospatial project director in Woolpert's Government Solutions market. The geographic information systems (GIS) professional has expertise that encompasses all aspects of the industry, with specialized knowledge of large-scale state, local government and federal mapping efforts. Moffat has served on the Tennessee Geographic Information Council (TNGIC) for 10 years and this year will serve as president elect.

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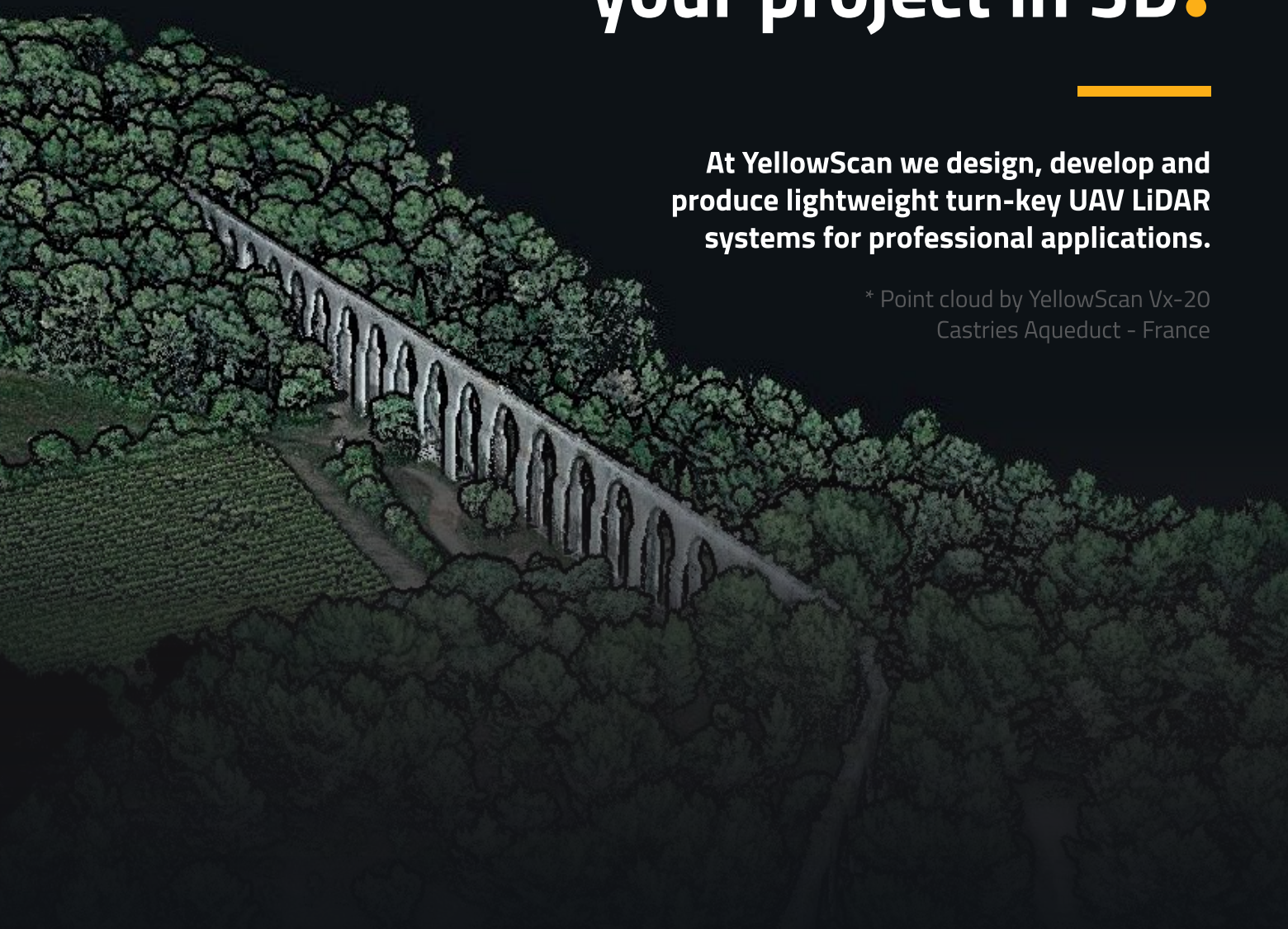

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From All Sides

Wreckage from the Dupont train derailment captured by a Trimble TX5 laser scanner. In total, four teams collected 82 scans and more than one billion data points in five hours.

Integrating laser scanning and UAV data gives investigators a new 3D view

No one would dispute that courage is at the core of any police officer. It takes a certain braveness to dress for a job in which every day is a mystery—people could go missing, be hurt, be fatally wounded—and one's own life could be at risk of injury or worse.

For detective Eric Gunderson of the Washington State Patrol (WSP), that fearlessness extends to his department's adoption and use of technology, where they regularly move beyond spec sheets to discover new and innovative ways to make technology work for them. For example, they once hung a Trimble TX5 laser scanner upside down through a sun roof to scan the inside of a car. (It worked).

This level of comfort with advanced technological tools has come from years of asking "What if," and a willingness—from the chief down—to embrace technology that can benefit both the WSP and the people it serves.

Laser scanners are now as common as radios for each of the WSP's 15 detective units across the state—the scanners have been in the field for the past four years. And in 2017, they began adding Unmanned Aerial Vehicles (UAV) to their arsenal of technology.

"Whenever we acquire new equipment, my captain always says, 'This technology is another tool in your toolbox,'" says Gunderson, the WSP's technology liaison based in Tacoma. "So, if you need a Phillips [screwdriver], you've got one. If you need a flat head, you've got one. No one tool will solve

BY MARY JO **WAGNER**

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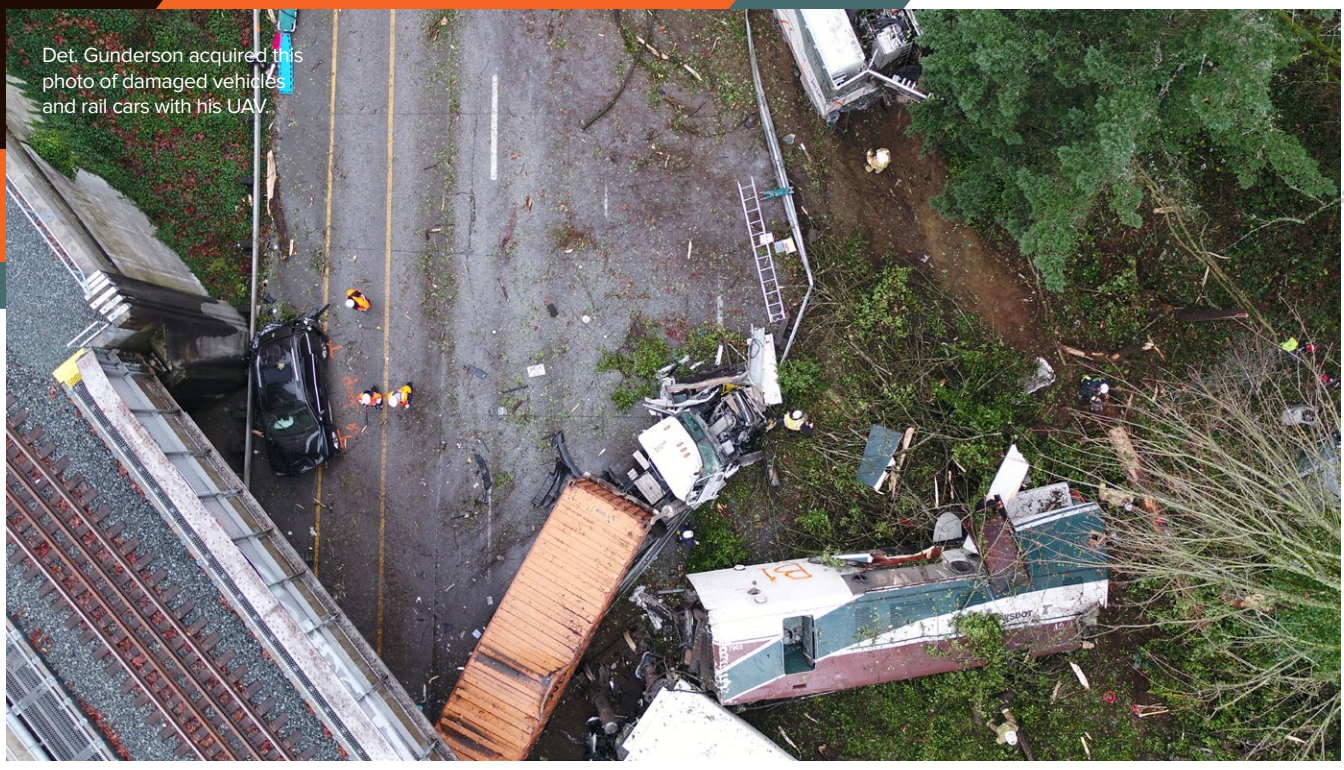


Det. Gunderson acquired this photo of damaged vehicles and rail cars with his UAV.

all your needs. It's important to get comfortable with many different tools both in the field and back in the office."

Indeed, Gunderson's penchant for experimentation has been key to becoming at ease with technology. Case in point: soon after acquiring their first UAV, Gunderson used Trimble RealWorks Forensics software to test the possibility of merging scan and UAV data of the same scene into one, integrated point cloud. It was not only a success; the integrated forensics view has become a formidable tool for accident reconstruction cases, which make up 65 percent of their responses.

Det. Gunderson operates the WSP's Matrice 200 UAV.

"Individually, both laser scanning and UAV have their strengths and benefits in the field," says Gunderson. "But the ability to seamlessly combine the two different data sources into one point cloud gives us a complete 3D view from all sides of a crime scene. That is an additional and powerful forensics tool. The technological versatility we have makes us confident that we'll be able to respond to any incident and investigate it thoroughly."

And it's a good thing, too. Because it was that same level of comfort with technology that gave WSP responders the confidence to answer the call to the 2017 DuPont train derailment outside Tacoma, Wash.—an accident so unpredictable and so massive that no training drill could have adequately prepared them. It not only put the WSP to the test, it provided the opportunity for Gunderson to push the limits of the integrated scanning/UAV point cloud approach and display it on a national scale.

Responding from all sides

On the crisp early morning of Dec. 18, 2017, an Amtrak passenger train was making its inaugural run between

Tacoma and Portland, Oregon. As it neared a curve leading to an Interstate-5 overpass near DuPont, the train was traveling at 78 mph—50 mph over the speed limit—and the lead locomotive, along with 11 of its 14 rail cars, derailed. It was 7:33 a.m. and I-5 was already teeming with commuters. The lead locomotive and three rail cars landed on I-5, causing a 14-vehicle pile-up. Three of the 77 passengers onboard the train were killed and 62 passengers and 6 crew members were injured. The initial damage was estimated to be $40 million.

"Where this happened couldn't have been a worse spot as far as impact to the region," says Gunderson. "I-5 is the major artery between Tacoma, Olympia, Portland and Seattle. With Puget Sound to the west, the Nisqually River to the south and a military base to the east, your only driving option is I-5."

WSP troopers were on scene within five minutes of the crash. By 8:30 a.m. the scene was swarming with hundreds of troopers, detectives, firefighters and paramedics, all of whom had one thing on their mind: rescue.

"For that kind of incident, the last thing you're thinking of is preserving evidence," says Gunderson. "If I need to move a train or car to get someone out, that's what's going to happen. So our first hour was consumed by all lifesaving first. But once we cleared the scene, everything began to slow down and we could start investigating. Then we owned the scene."

Working in collaboration with the National Transportation Safety Board (NTSB), the lead investigating organization, Gunderson led the accident reconstruction phase, bringing in four Trimble TX5 scanners and one DJI Matrice 200 UAV. Although he had been successfully using Trimble RealWorks Forensics to merge scan and UAV data into point clouds, he had never applied the approach to an incident of this magnitude.

Teams of WSP collision investigation detectives first walked through the debris-riddled scene, taking photographs, painting the footprints of important objects such as cars and tire marks, and documenting them. In parallel, he dispatched two teams per each of the four TX5 scanners and split them into two groups, one to work on the overpass section and one to manage the roadway section.

Gunderson integrated scanning data and UAV photos into Trimble's RealWorks software to create a 3D point cloud of the incident scene. In this view, orange markers indicate the location of each of the 82 set ups taken with the Trimble TX5.

Setting up on each end of the tracks, the railway teams methodically moved towards each other, scanning all four sides of the individual rail cars and any strewn debris, and recording each object as it was found. The ground crew followed the same process. Starting at each end of the I-5 scene, the teams collected data points of the rail cars, vehicles, roadway, tire marks, paint marks, and anything that lay within the boundaries of the accident. In total, the four teams collected 82 scans and more than one billion data points in five hours.

"What's awesome about scanning is that it ensures you don't miss anything," says Gunderson. "At the accident scene, you only get one shot to get what you need. You can't put the trains back where they used to be, so you need to be right the first time. Scanning captures everything incredibly quickly and often captures something you didn't know you'd need."

While the teams were scanning the tracks and roadway, Gunderson flew the 920-ft-long by 340-ft-wide scene with the UAV. After a 10-minute set-up, he flew an overall pass at 200 feet at roughly 70 percent front lap and 50 percent side lap to establish a base. He flew a second pass at 100 feet and a final flight at altitudes between 15 feet and

50 feet to acquire some oblique photos. In 89 minutes, Gunderson collected 682 photos with the unit's 20MP camera.

"I could've handled the accident with just one technology, but given its scale, I wanted to have data redundancy," says Gunderson. "The drone would provide different view angles since the scanner can't get the top of the train. In addition, with the volumes of data I'd collect, it would be a great opportunity to test how well I could merge the two massive datasets together."

By 2:00 that afternoon, Gunderson was able to pack up the gear and head back to the office to process the data.

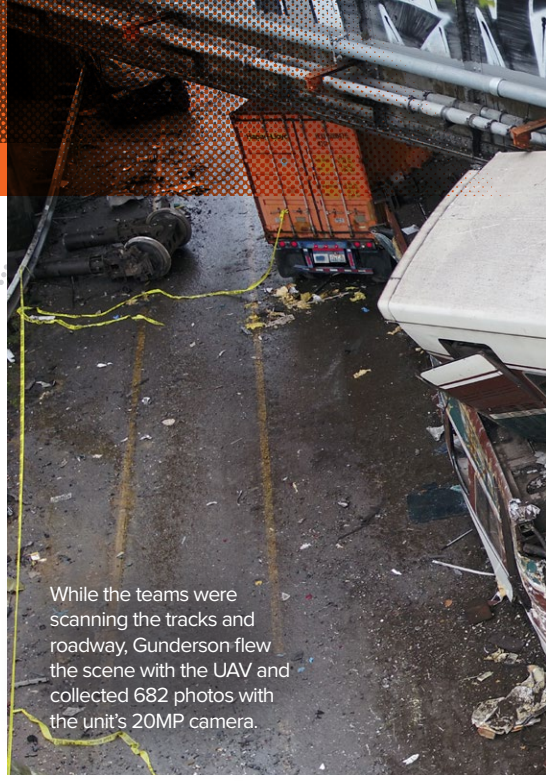
Creating a complete 3D picture

For efficiency, Gunderson loaded the UAV photos into their photogrammetry software for batch processing overnight, so when he returned to the office the next morning, the data would be ready.

Preparing the 3D point cloud began by importing the 82 scans into the RealWorks software, which allows investigators to quickly register, segment and classify 3D laser scan data for analysis and reconstruction. As there was data from four different scanners, Gunderson had to first group and register, or stitch together, all scans from each scanner to produce four scan-data groups. Then he merged each of the four groups to create one overall point cloud.

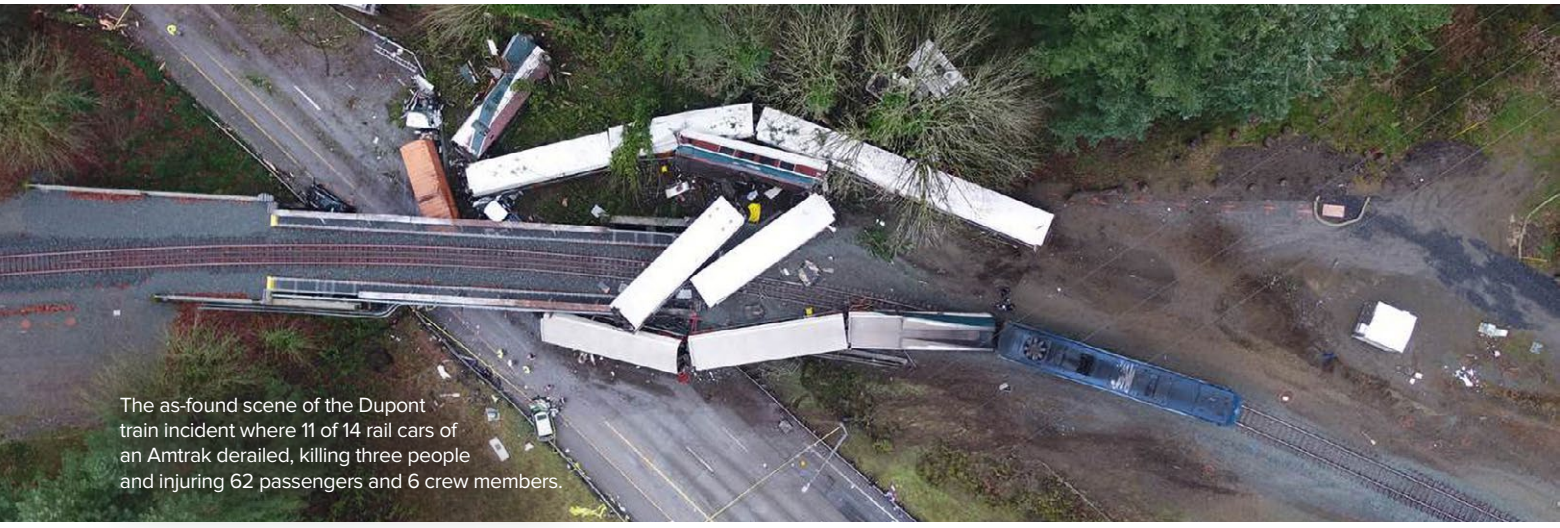
Since teams were collecting data during the active accident investigation, the scanners also captured the hundreds of responders working the scene, which resulted in superfluous or "parasite" points. RealWorks provides automated clean-up tools to help clear unneeded points. With the automatic classification feature, he moved irrelevant objects into designated layers and removed the parasite measurements from the finished point cloud.

"RealWorks' ground extraction tool is excellent," says Gunderson. "I can separate the ground from another layer, and then cut out the parasite points like the police cars, fire trucks, and people walking around so I can produce the clearest model possible. Being able to almost freeze the scene gives us more confidence when investigating after the fact."



While the teams were scanning the tracks and roadway, Gunderson flew the scene with the UAV and collected 682 photos with the unit's 20MP camera.

> "At the accident scene, you only get one shot to get what you need. You can't put the trains back where they used to be, so you need to be right the first time."



The as-found scene of the Dupont train incident where 11 of 14 rail cars of an Amtrak derailed, killing three people and injuring 62 passengers and 6 crew members.

With the laser scan point cloud complete, Gunderson focused on importing the processed UAV point cloud into the RealWorks point cloud. Once imported, he used the automated extraction tool to clean up and remove any superfluous points and then combined the dataset with the master point cloud to produce the final 3D model of the train derailment. The two came together perfectly, he says.

"Integrating UAV data into RealWorks is nearly seamless because the software views the data as a .las (laser scan) file," says Gunderson. "Pairing the tops of the train cars from the UAV data with the scanning data of the cars gives us a complete view of the incident scene, and one we wouldn't have if we had just used one technology. You can spin the model, rotate it, move along any axis, measure anything and zoom in. It's just like being there."

In total, it took Gunderson about nine hours to create the finished incident model. In less than 36 hours after the initial derailment, he was able to provide a 3D view of the entire accident scene and any object in it.

That afternoon he presented the NTSB with the 3D data and "walked" the officials through the point cloud, demonstrating its visual content and its capabilities.

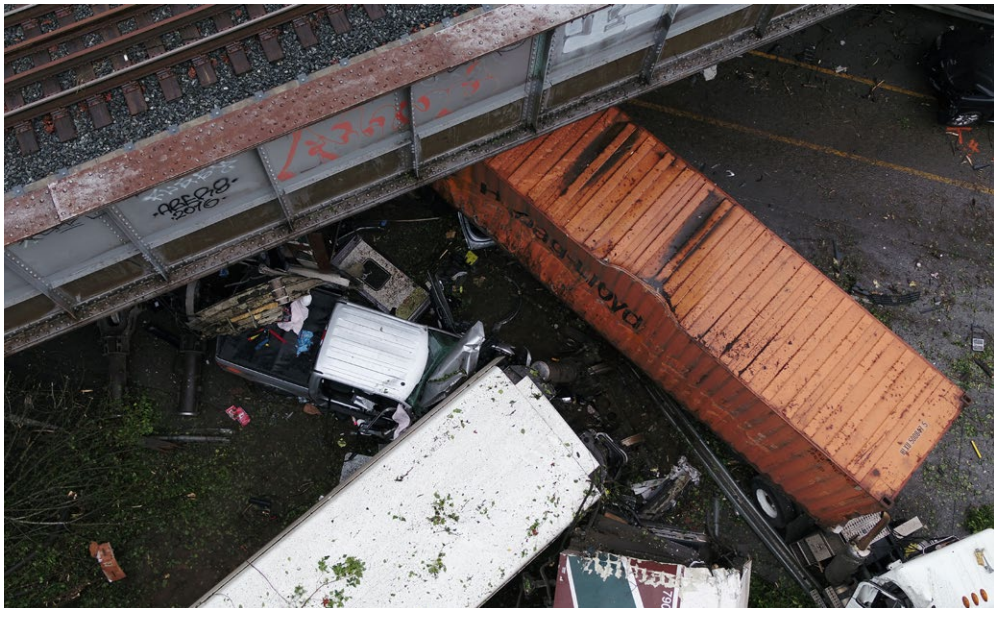
"They were wowed by the model," says Gunderson. "I don't think they'd ever seen something like this before and as I moved through the scene, they could immediately see the benefits of the detail, accuracy and interaction the point cloud provides for their investigation. They can now revisit the scene from their desktops anytime they need to find evidence or verify details, and they may even find something new to aid the analysis."

The NTSB is expected to issue its final report on the accident in 2019.

Value for money

The final point cloud result of the DuPont train derailment not only demonstrated the success of Gunderson's multi-pronged approach on a large scale, it helped cement these technologies as core data sources for the WSP.

"The benefits of the laser scanner and the UAV are unparalleled, both individually and together," says Gunderson. "I can't fly the UAV in a house, but I can definitely scan it. But if I have a mile-long accident scene, I can fly that in five minutes, and I can supplement with the scanner. I can capture great scanning data at each end of the scene and then connect the two in



WSP troopers were on scene within five minutes of the crash. Search and rescue consumed the hundreds of troopers, detectives, firefighters and paramedics for the first two hours.

RealWorks. Having these choices allows us to tackle any scene."

Last summer, the department upgraded their scanners and acquired three Trimble TX6 laser scanners. The new units give them 500,000 points per second, better intensity detail, which makes objects stand out more clearly, faster scanning and the ability to scan in the rain—an important feature for the Pacific Northwest.

They also launched a UAV pilot program last July and outfitted 15 collision technology specialists across the state with smaller UAV units. The aim was to assess whether the technology could help them map straightforward accident scenes more efficiently and accurately. Soon after the pilot began, a team responded to a one-car pedestrian accident on I-5. Prior to the UAV, they would have worked the scene for a few hours with traditional baseline methods. Using the UAV, they cleared the scene in 18 minutes.

> "The benefits of the laser scanner and the UAV are unparalleled, both individually and together. Having these choices allows us to tackle any scene."

"Someone from the state DOT (Department of Transportation) once told me that any time the I-5 is shutdown, the cost to the region is about $350-$400 a minute," says Gunderson. "That adds up to a big number really quickly."

Based on the success of the pilot, the WSP is adding 75 more smaller UAVs to its force this summer and more than 50 WSP detectives have been issued the smaller UAVs—each criminal investigation division has a Matrice UAV.

It's clear the WSP's commitment to asking "What if" and investing in technological choices is not abating. In a job that demands that officers and investigators are ready for any possible scenario at any time, enabling technology is a welcome tool.

"Pushing the envelope with our technology is having a huge impact," says Gunderson. "It's almost unmeasurable to account for what we capture and the impact that data has on the people we serve. We could never have trained for an incident like the derailment. But when it happened, we didn't hesitate to respond because we knew we had the technology and tools we needed. You're going to have victims who want answers and investigators who have to give those answers. Our ability to provide information that will help people find the answers feels really good. And that's real value for money." ■

A TX5 stands protected by the elements as it scans the mangled rail car in front of it.

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

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Figure 1: Harris H6 hybrid UAS equipped with LiDAR USA Snoopy A-Series HD sensor.

Skytec Completes Frigid Upper Peninsula Hybrid UAS Success

Longer flights and lidar payloads yield consistent data acquisition for Tennessee team

During a frigid late-November trip to Michigan's Upper Peninsula,the Skytec team needed UAS and lidar equipment to perform well in harsh weather. The equipment delivered, warming the hearts of our clients and our freezing flight crew.

When Skytec[1] packed up its equipment in Chattanooga, Tennessee to travel roughly 1000 miles to a job site in Michigan's Upper Peninsula, the weather couldn't have been more different than what it would eventually endure. November in Tennessee is a mild month, barely hinting at winter to come. In the Upper Peninsula, however, winter was already fully entrenched. This acquisition mission would push the upper thresholds of lidar collection capabilities from an unmanned system in cold, snowy conditions.

Skytec knew this would be challenging, but the team was confident that the equipment and expertise it would be bringing to the site would be more than enough to complete the mission without incident. It turned out that they were right, though the bone-chilling temperatures did result in frozen fingers, toes and noses.

1 skytecllc.com

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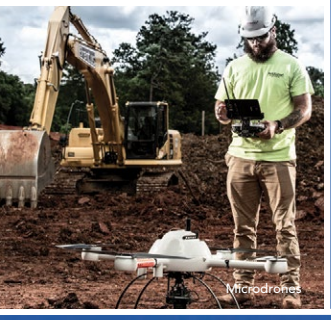

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Figure 2: Field preparations and pre-flight in the Upper Peninsula

A two-party Tennessee excursion

Skytec's venture to the Upper Peninsula arose from a combination of interesting relationships and circumstances.

Skytec was co-founded by Andy Carroll and Bill Rogers, who serve as Chief Technology Officer and Chief Executive Officer respectively. The company is a leader in unmanned aerial systems, remote sensing, and GIS technologies. Its tagline, "Acquire, Analyze, Inform", points toward its service model. it uses its UAS fleet and imaging tools to *acquire* site information, *analyze* that data using in-house GIS and remote sensing expertise, and creates the opportunity to help *inform* consequential decisions made by its clients.

Skytec has teamed with a myriad of partners from across the country on projects ranging the full spectrum of complexity. One of those partners has been Wingfield Scale & Measure[2], also based in Chattanooga, which specializes in industrial weighing and measuring solutions.

Wingfield, a third-generation family business, maintains a robust collection of terrestrial lidar systems and expertise. But for a particular client, who needed a two large mining sites assessed in the Upper Peninsula, an aerial lidar option made the most sense. The client needed to measure the volumes of overburden materials that would be cleared from its sites as well as the remaining surface materials. This job would require aerial lidar due to the vast areas to be captured, over 2400 acres, and densely forested conditions on site.

The Wingfield team, therefore, reached out to Skytec.

Tough terrain and harsh weather—a good UAS fit

The weather awaiting Skytec in the Upper Peninsula was in stark contrast to what the team had been enjoying in Tennessee. Whereas Tennessee's November temperatures often creep into the mid-60s, snow was already blanketing the ground at the Michigan job site with cloud-filled skies and windy conditions.

Historically, the kind of job for which the team was preparing would require extensive groundwork by field crews or the acquisition of lower-resolution data from manned aircraft. With the frigid weather conditions, snow, and low cloud ceilings, however, manned aircraft would have had a very difficult time collecting the required data.

Skytec's lidar and UAS tools

To meet the client's needs head-on, Skytec decided to use its brand new Harris H6 hybrid system (**Figure 1**). The H6 is a heavy-lift gas/electric hybrid-powered UAS, capable of flight times surpassing 1.5 hours in fair conditions while equipped with lidar payloads.

The lidar selection was Skytec's LiDAR USA Snoopy A-Series HD system. This Velodyne HDL-32E-based system maintained a low to moderate weight of 2.51 kg and high-density scanning capability of greater than 200 pulses per square meter at an elevation of 60 meters above ground level. Coupled with the hybrid-powered system, this enabled the flight team to plan for flight times greater than one hour, leaving adequate fuel reserves for unexpected conditions.

Tough weather, no problem

Given the testy weather Skytec knew it would encounter, the team assumed that the maximum performance of the equipment would be tough to achieve. Yet even in those harsh, sub-freezing temperatures, the hybrid UAS performed quite well (**Figures 2, 3** and **4**). Thanks to the high-quality system,

2 https://www.wingfieldscale.com/.

Figure 3: Harris H6 and lidar payload ready for take-off.

Skytec enjoyed three great benefits:

1. **Extended flight times:** The system was able to achieve more than 76 minutes of flight time on a single mapping grid with the UAS. On that grid, the flight covered an area of 700 acres with a dense point cloud through snow, wind and forest canopy. If Skytec had used an all-electric system with lithium batteries only, the team would have been significantly limited due to weather conditions, expecting to see flight times of only 10-15 minutes, at best, in the daily high temperatures of 15°F.
2. **Enhanced Line of Sight Range**: With a 2.3 meter arm-to-arm diameter and 2-stroke engine, the H6 remained easily visible and audible from distances up to 1900 meters away. The system was easily tracked and located on the horizon during mapping grids over the mining site. Skytec's Desert Rotor ground control station, operating at 900 MHz with a dual-antennae system, maintained relative connectivity at 97% signal strength or greater. This ability to fully control and track the H6 at great distances instilled a high level of confidence with the flight team in the field.
3. **Consistent data acquisition:** Because the hybrid UAS could fly for much longer durations, Skytec was able to collect high-accuracy data much more consistently. Before Skytec added the hybrid system to its fleet, the lidar field data collection process was,

Figure 4: Harris H6 and lidar payload in flight on a frigid day.

literally, "stop-and-go". A typical grid flight would consist of starting the system, beginning a grid flight line, collecting data, landing to change batteries, launching again, collecting more data, etc. — over and over. The constant change in heading and elevation, sensor restarts, and fluctuating power supplies places additional computational requirements for positioning and sensor inertial measurement units. That increased work typically introduces errors and lowers the overall consistency of the data. With the hybrid, Skytec was able to significantly reduce the introduction of these sources of error.

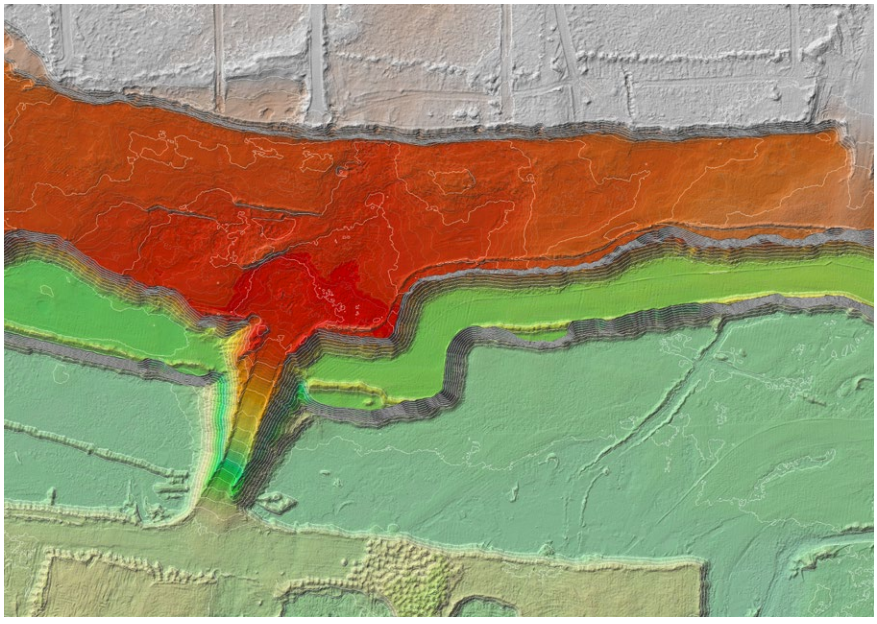

Figure 5: Lidar-derived deliverable for Skytec/Wingfield shared client.

Great data acquisition equals quality mapping results

Thanks to the exceptional performance of the UAS, Skytec was able to acquire reliable data in a comparatively short time. The next step was to parse that information into a comprehensible, actionable format for the client shared with Wingfield.

Raw lidar data and control points collected by post-processed GNSS base observations were fused with telemetry records in Novatel's Inertial Explorer and LiDAR USA's Scanlook software. LAS files were ground-classified using automatic and manual classification techniques. GeoCue's LP360 and Esri's ArcGIS Pro were used to perform final tiling and accuracy reports. The client received classified LAS v1.2 files and digital terrain model products (**Figure 5**) at USGS QL0 standards.

Elevation surfaces were derived from the digital terrain models and used in CAD software to quantify anticipated volumes of overburden materials and volumetric changes for stockpiles. This provided the client with a greatly increased level of accuracy for volume estimates. These estimates were used for budgeting and progress tracking throughout the year. Overall, the client was provided with a higher accuracy dataset, in a shorter amount of time, representing excellent value in terms of product and price.

Heading home

In all, the combined Skytec/Wingfield team spent roughly a week on the Upper Peninsula site. In retrospect, in addition to a renewed appreciation for Tennessee Novembers, the team learned a great deal about how some of the newest technologies in the UAS and lidar industries function in harsh circumstances.

The team was delighted with how the hybrid performed and yielded downstream results in terms of data acquisition and analysis for the shared client. Without quality unmanned technology, it would have been difficult to obtain the kind of reliable information the client needed about its mining sites.

Skytec fashions itself as a UAS/lidar early adopter. The experience in Michigan was heartening in that it demonstrated a remarkable advance in the technology space in which the company operates. Skytec, therefore, is hopeful further innovations are available to it soon, enabling it to address new client challenges.

After 15 years in the higher education space leading the Interdisciplinary Geospatial Technology Lab at the University of Tennessee at Chattanooga, **Andy Carroll**[3] co-founded Skytec, LLC in 2015 with Bill Rogers. Andy serves as Chief Technology Officer.

3 linkedin.com/in/andrewcarroll67

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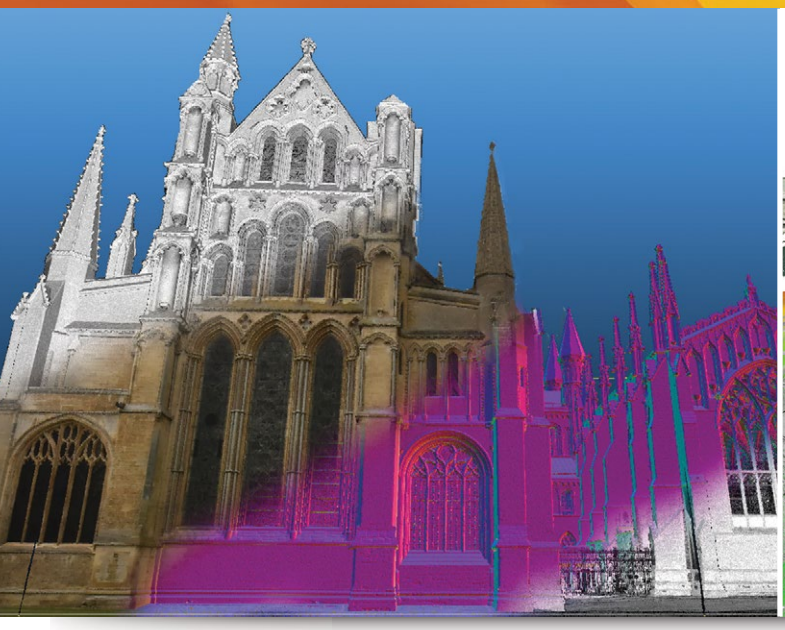

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Geomagnetic Declination

Using Land Surveys, Lidar, and Stone Walls

(1685–1910)

My first experience with stone walls was as a young kid (6-10 years old) living in South Deerfield, NH. The family home was the site of an abandoned farmstead consisting of massive stone foundations of quarried granite and stone walls throughout the woods. Decades later while living in a rural setting outside Albany, NY, I renewed my childhood fascination by mapping about 6 miles of stone walls in the nearby woods using a handheld GPS unit. The resulting map showed a complex pattern that made no sense until a 1790 map of property boundaries in the town was located. Upon recognizing the geophysical potential of these stone walls, I mapped 726 miles of stone walls in New Hampshire (312

Figure 1: Google Earth image showing the ground in the lidar image (Figure 2) in Henniker, NH to be obscured by the forest canopy. Width of view is 0.67 mile.

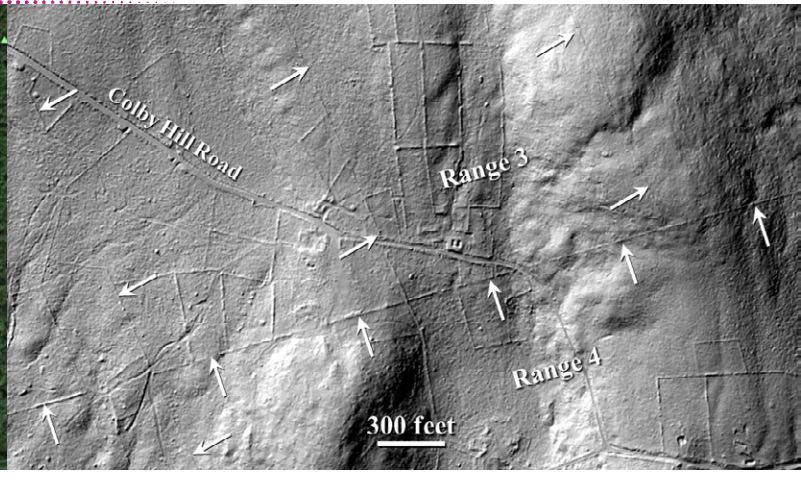

Figure 2: Lidar image from the *NH Stone Wall Mapper* showing a 0.7-mile segment of the ENE-trending, stone wall-defined boundary between Ranges 3 and 4 in a heavily wooded area (43.1887°N; 71.8789°W) near Colby Hill Road in Henniker, NH. This boundary was laid out by Matthew Patten's survey team on Thursday, October 5, 1752 using a magnetic compass-bearing of N84°E. The bearing relative to True North is N74.4°E, which yields a magnetic declination of 9.6°W in October 1752. The geomagnetic field model *gufm1* also gives a value of 9.6°W for the magnetic declination at this location in late 1752. The NW-trending boundaries for lots # 17 and 18 had a magnetic bearing of N15°W in the original survey. Many other stone walls are also visible in this view, but were not built along the original 1752 boundaries.

BY JOHN W. DELANO

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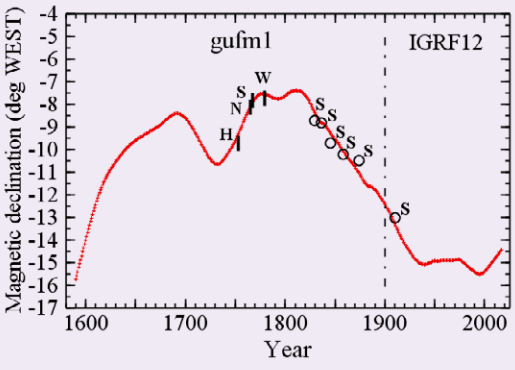

Figure 3: 233 miles of stone wall-defined boundaries in Henniker (H; 41 miles), Nelson (N; 38 miles) Stoddard (S; 141 miles), and Windsor (W; 13 miles) were mapped using lidar images to determine the magnetic declination at those locations based on land surveys conducted in the latter half of the 18th century. Those magnetic declinations are shown plotted against the gufm1 (pre-1900) and IGRF12 (post-1900) geomagnetic models (red curve). With the exception of the time-interval of 1775-1810 for surveys at other localities in New Hampshire and New York that differ from the geomagnetic models by up to 1.5-2.0° eastward, the differences between the declinations inferred from the stonewall-defined boundaries and the geomagnetic models are usually less than 0.5°.

miles) and New York (414 miles) using old land surveys and lidar images. The results of that work have recently been accepted for publication in the *Journal of Geophysical Research: Solid Earth*. The title of the article is … *Measurements of geomagnetic declination (1685-1910) using land surveys, lidar, and stone walls* (scholarsarchive.library.albany.edu/cas_daes_scholar/5).

Lidar images with resolutions of about 3 feet are required to locate and map stone walls. The *NH Stone Wall Mapper* (granit.unh.edu/resourcelibrary/specialtopics/stonewalls/) described by Rick Chormann, State Geologist and Director of the New Hampshire Geological Survey, in the February 2019 issue of the NHLSA Newsletter provides a complete set of processed lidar images for all of New Hampshire. This is a superb resource!

While finding stone walls on lidar images is straightforward, interpreting them is a different matter. Which walls were constructed along property boundaries? When were those property boundaries surveyed? Those two questions consumed most of my effort. Historical literature for each locality (Appendix 1 in JGR article) was needed to ultimately determine the date and magnetic bearings of the original land surveys, especially of townships. New Hampshire has an excellent compilation of that historical information (e.g., volumes by Albert Stillman Batchellor that are available on-line: sos.nh.gov/Papers.aspx). Those searches of the historical literature sometimes led to accounts from 18th century survey teams that had been commissioned to lay out hundreds of ~100-acre lots along range boundaries, many of which are still defined by old stone walls in New Hampshire and New York.

The diary of Matthew Patten, who was in charge of a metes-and-bounds survey in 1752-1753, described the daily challenges of rough terrain and harsh weather as his team of axmen, chain-men, and surveyors laid out hundreds of lots in 45 miles^2 of rugged wilderness in Henniker, NH (L. W. Cogswell, 1880. *History of the Town of Henniker, Merrimack County, New Hampshire, from the date of the Canada Grant by the Province of Massachusetts, in 1735, to 1880*. Republican Press Association, Concord, NH. 868pp). Using those detailed accounts, it was possible to track the paths of Patten's survey team along the range boundaries and to identify the team's location on lidar images during notably difficult times. Such accounts with the lidar images have fascinated public audiences. **Figure 1** shows stone wall-defined boundaries laid out by 1752 surveys in northeastern Henniker.

Stoddard, NH was fortunate to have a surveyor and dedicated historian, Charles L. Peirce (1874-1963), who generated a detailed map of lots and ranges (stoddardnh.org/about-us/pages/charles-peirce-maps-stoddard) that were laid out in the original survey in 1768-9 and are often defined by stone walls today. Although none of the stone walls are continuous from one side of the town to the other, most can be extrapolated among the current remnants to define a systematic grid. Mapping stone wall-defined boundaries along ranges and lots defined by the original survey in Stoddard, and those in nearby towns, the magnetic declinations at those locations were determined and compared with the current geomagnetic model, *gufm1* (ngdc.noaa.gov/geomag-web/#declination). **Figure 3** show excellent agreement. However, as documented in the forth-coming JGR paper, a systematic difference of 1.5-2.0° in magnetic declination (i.e., more eastward than *gufm1*) was found for surveys done in 1775-1810 at other regions of New York and New Hampshire. Local magnetic anomalies

in the earth's crust are not considered the likely cause of the geographic extent, magnitude, and direction of that difference. The *gufm1* model apparently needs revision during that time-interval.

In summary, stone walls that were built by the early settlers along boundaries laid out by the original land surveys of New Hampshire townships still exist. With knowledge of the original land surveys and the use of lidar images (NH Stone Wall Mapper), those stone wall-defined boundaries can be distinguished from the myriad of other walls within a township. Although the boundary walls are often intermittent, lidar images allow the original boundaries, where stone walls are absent, to be located between existing stone wall segments by interpolation. Finally, the current geophysical model, *gufm1*, provides a good description for changes in the magnetic declination since the late 17th century, except for the interval 1775-1810 when the declination was apparently 1.5-2.0° eastward of the gufm1-derived value. ■

Note: This article appeared in the April issue of the New Hampshire Land Surveyors Association TBM and is reprinted by permission.

John earned a Ph.D. in Geology at Stony Brook University, State University of New York, in 1977. His research was competitively funded by NASA and/or the National Science Foundation (NSF) for nearly 35 years and resulted in 70 professional publications. John served on, and chaired, scientific advisory panels for NASA and NSF, and was the Associate Director of NASA's Astrobiology Institute, which was multi-institutional research consortium headquartered at Rensselaer Polytechnic Institute. He retired from his academic career at the University at Albany in 2017 at the rank of Distinguished Teaching Professor in the Dept. of Atmospheric and Environmental Sciences and Associate Dean for the College of Arts and Sciences. John and his wife, Susan, are currently residing in Williamsburg, VA.

Figure 4: Area in Sullivan and Merrimack counties of New Hampshire with some of the stone walls (pink lines) have been mapped
NH Stone Wall Mapper: granit.unh.edu/resourcelibrary/specialtopics/stonewalls

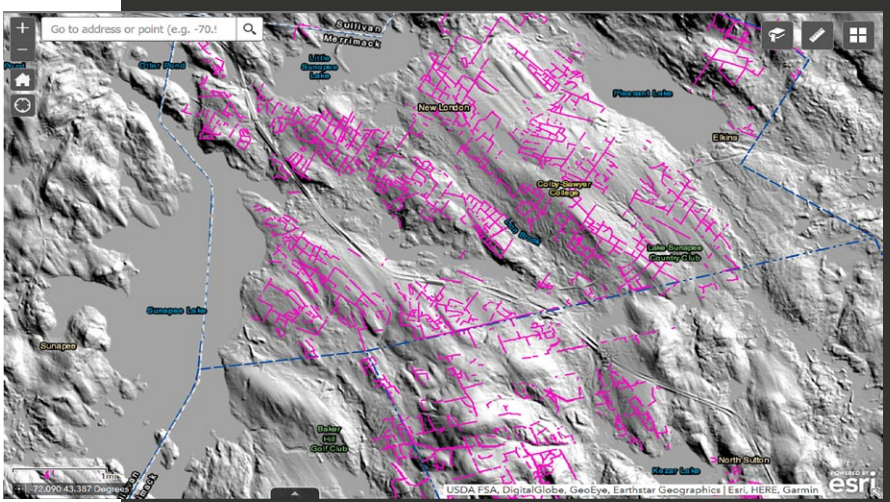

Figure 5: Lidar image of the same area shown in Figure 3 showing the abundance of stone walls. Most of these stone walls were built by 18th and 19th century farmers, many of whom subsequently left the area. The forests soon reclaimed the fields that had been bordered by stone walls.

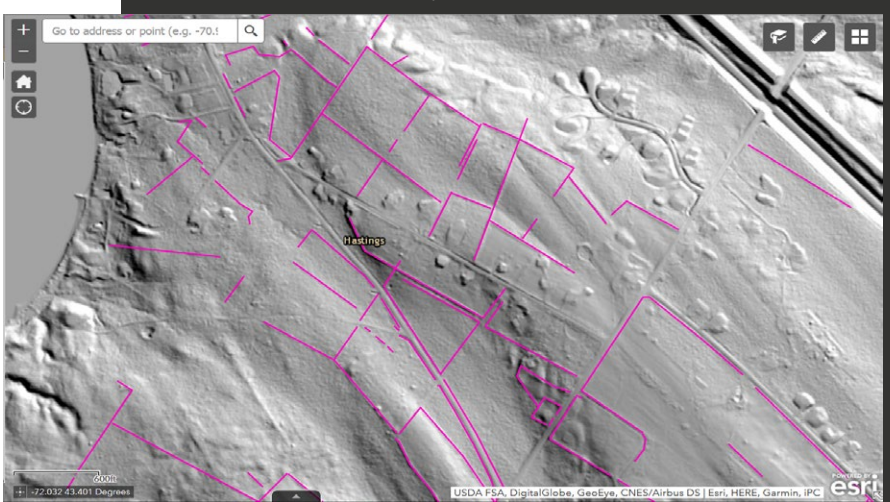

Figure 6: Lidar view of area from Figure 4 stone walls (pink lines), eastern portion of Lake Sunapee (left edge) Routes 103A (center), and US Route 89 (upper right corner). Width of view is about 1 mile.
NH Stone Wall Mapper: granit.unh.edu/resourcelibrary/specialtopics/stonewalls

Cloud-hosted Web-based Lidar Data Storage and Dissemination Solutions—Part 1

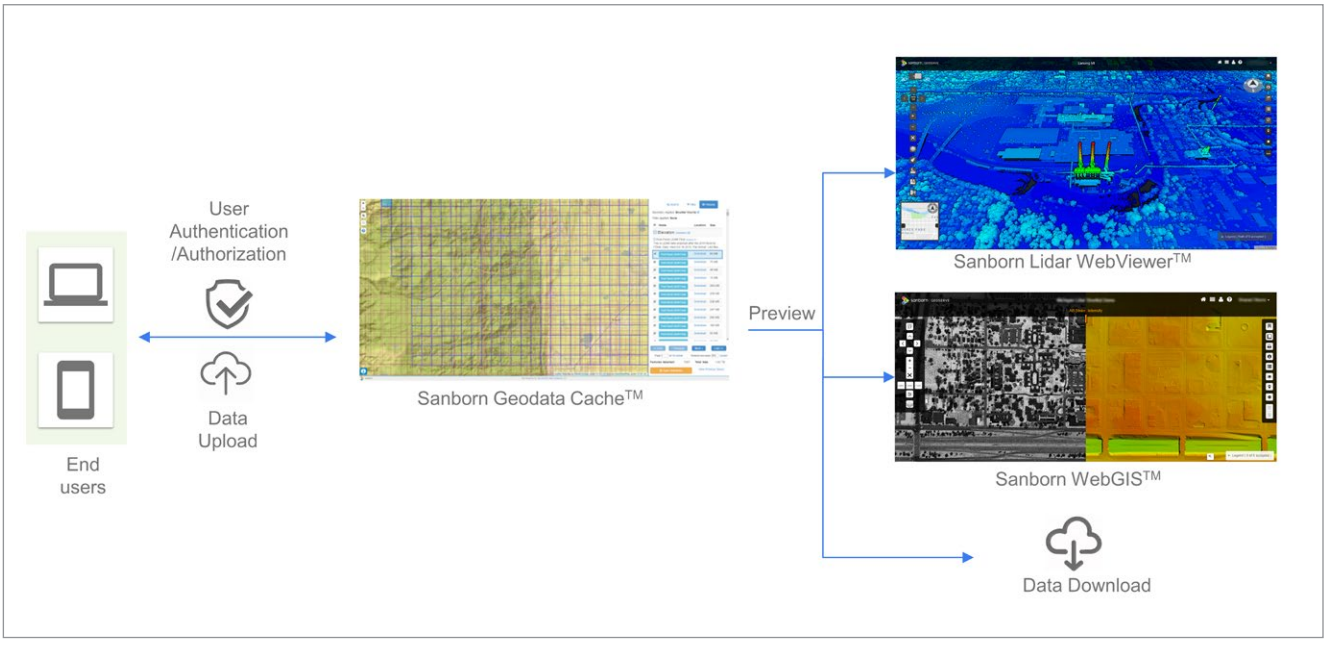

Figure 1: Sanborn GeoData Cache™ application workflow: Users can login from tablets/laptops, search for the datasets, view them online in web-based interfaces and download them, if needed.

The increasing use of lidar in multiple applications has resulted in a flood of temporal lidar data and has created the logistical challenge of storing, managing and retrieving data for distributed end users. The Sanborn Map Company, Inc. (Sanborn), has developed a cloud-based solution for managing the data discovery and dissemination of lidar from various data sources, ranging from data storage, data discovery, and feature extraction through to data visualization over the web. The end users can easily access and manipulate the data using a standard web-browser and no longer have to worry about storing, accessing, and processing. Since the entire pipeline is hosted and managed on the public cloud, it is infinitely scalable, responsive to increased user loads or processes in real-time and has a 99.9% Service Level Agreement (SLA) with guaranteed uptime.

In this article, we present the complete lidar data pipeline as managed in our spatial database framework and hosted in the public cloud, for a typical

BY SHARAD **OBEROI PHD** AND SRINI **DHARMAPURI PHD**

statewide customer, as an example. This is a two part paper: in this article, the framework and use case for the lidar data storage and dissemination is discussed; the technical challenges regarding implementation, along with the recommended best practices, will be presented in Part 2.

Current Bottlenecks

Data management is a challenge for most enterprise customers. A landmark study by the National Institute of Standards and Technology (NIST) found that 40% of engineering time is spent locating and validating information. Lidar data management for enterprise customers can become complicated when different data sources are used to generate new products or multiple teams share data creation. For example, if "Team A" created a digital elevation model (DEM) from a quality level 2 (QL2) dataset without documenting its source metadata, it can quickly make the downstream work done by "Team B" lose track of the limitations of such a product. Many corporations solve such problems by strictly documenting the processes and workflows through control process documents. However, there are limitations to that approach as maintenance and documentation itself becomes a significant overhead effort. Making the data more accessible can have positive cascading effects across multiple departments within an organization.

The smartphone app industry has shown that making dedicated applications for specific tasks without requiring the end user to learn proprietary software can have enormous positive advantages. For example, a photo-editing app that allows users to perform a set of useful actions such as mirroring images, cropping out faces or even changing specific colors, can be empowering for a casual user who would not know how to do this in Photoshop®, does not have access to Photoshop®, and/or is not necessarily interested in obtaining Photoshop®. Using the same paradigm, allowing end users to perform actions with the lidar data like elevation profiling and point density calculations without needing access to a specialized desktop/workstation with the necessary software installed, is game-changing.

> "The rapid growth in lidar data volumes and collection frequency has led to increasing pressures on the limited resources of enterprise data managers."

Historically data storage has been a stubborn bottleneck challenge for enterprise customers interested in data management. The advent of the public cloud has been revolutionary as organizations can now deploy solutions in the cloud, thus eliminating concerns about future scalability and SLA uptime. Global load-balancing technology can be implemented to help distribute incoming requests across pools of instances in multiple regions, to achieve maximum performance, throughput and availability. These load-balanced virtual machine clusters can automatically scale the capacity up and down based on the end user traffic, providing a reliable performance for the organization. Object-level permissions and encryption during transit and at rest ensure the data's confidentiality, and protect against potential information security concerns.

Use Case

Consider the following scenario: An end user needs lidar data for a given area of interest (AOI). The user logs into the Sanborn GeoData Cache™ website, sees the different datasets available and narrows down the search to the desired AOI, based on geographic and attribute filters. Using the Sanborn Lidar Web-Viewer™, the user can analyze the quality of the data and perform useful geoprocessing tasks such as elevation profiling, measurements, vector overlays, or changing the point cloud display method. Once satisfied, the user can clip the data and download it for immediate offline consumption. The workflow available to the end user is summarized in **Figure 1**.

Sanborn's Solution

Sanborn has a long history of developing and implementing technological innovations to solve real-world geospatial challenges. In order to reduce the overhead required for hosting and maintaining the data, Sanborn has created an end-to-end solution to facilitate data discovery and dissemination for our customers. Sanborn GeoData Cache™ product allows users to search through lidar datasets to identify and access the data in which they are interested. The end user is then

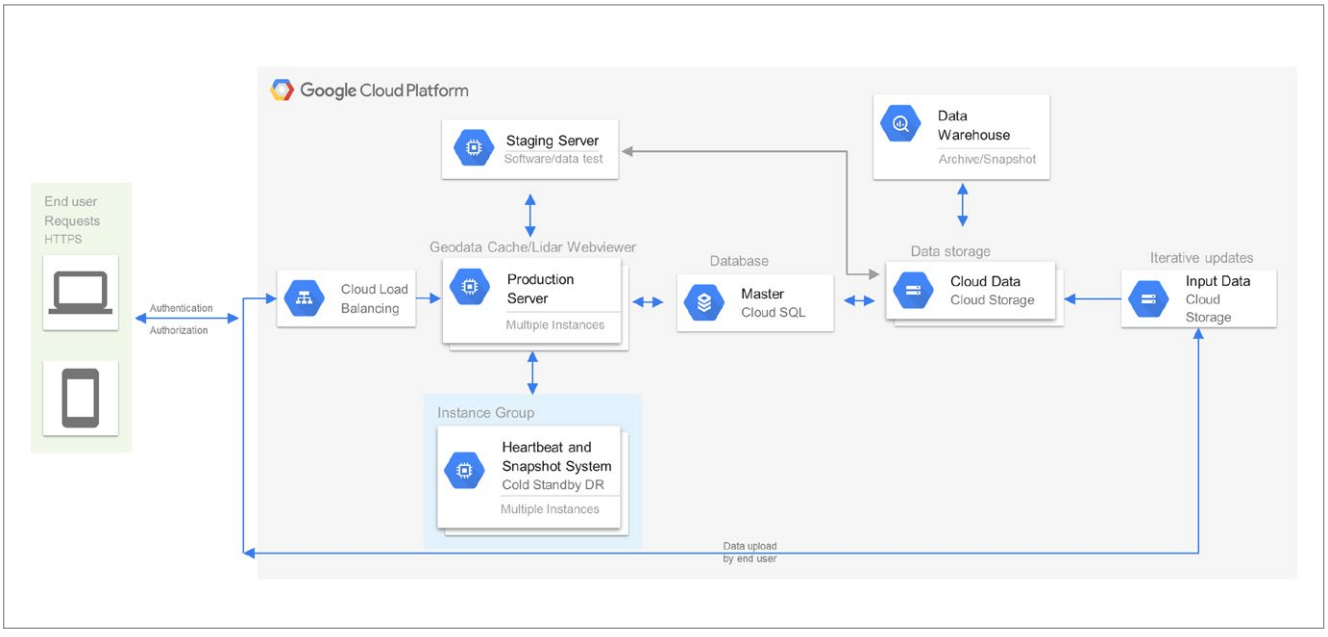

Figure 2: Architecture Diagram for Sanborn GeoData Cache™, as deployed in Google Cloud Platform (the application itself is cloud-agnostic)

able to (a) download the data; (b) view a raster version of the data served as a WMS/WMTS in any OGC-compliant software; and/or (c) view it online in Sanborn Lidar Web-Viewer™. Sanborn Lidar Web-Viewer™ can integrate with vector layers (point, polyline or polygon shapefiles/geodatabases), which allows users to manipulate the point cloud in 3D, measure features, add annotations and export screenshots. An architecture diagram of the Sanborn GeoData Cache™ application is shown in **Figure 2**.

Using Sanborn GeoData Cache™, the users can query for data AOIs that meet their specific conditions. Once a selection is made, users are presented with a list of attributes for all polygons selected. Features can be sorted based on geographic boundaries or attribute filters, and users can set the geographic boundaries by entering criteria into the search text box, such as city, county, or other tags; latitude/longitude coordinates; or bounding box coordinates. They can also apply the bounding box of the current map-view by selecting it on the map. The data can also be searchable through other GIS layers, using layer attributes, or through a spatial query using route indexing, coordinates, project-site polygons, etc. Each of the AOI footprints is displayed in a list on the results sidebar and as a wireframe on the map interface. Restrictions can be applied on individual users to allow the download of a predetermined number of tiles at a time, monthly download limits, or even require admin-approval before bulk downloads.

The attribute filters applied on top of a boundary filter can include:

- **Agency Selection:** Users can select for the agency which collected the data
- **Data Quality:** Users can select data by specifying the quality parameters
- **Collection Method:** Users can select data by entering the collection method used for acquiring the data (terrestrial or aerial)
- **Cloud Cover Percentage:** Users can filter the data by entering a maximum amount of cloud coverage allowed in a feature
- **File Format:** Users can select the format in which the downloadable files will be provided
- **ISO Category:** Users can select the ISO category desired for a selected data type
- **Licensing:** Users can select for data licensing permissions in the selected data
- **Acquisition Date Range:** Users can select features based on a date range (all features outside the range will be removed)

Authentication & Authorization

Sanborn GeoData Cache™ solution allows end-users to access data through browser-based authentication. Multi-factor authentication (MFA) can be offered as an additional factor to conventional logins to prevent unauthorized access. MFA is used for both authentication (the action of verifying a user's identity) and authorization (the action of verifying a user has permission to do something). The additional factor to conventional logins can be done through sending a one-time password by SMS, or email, or through apps like Google Authenticator and Duo.

The Sanborn GeoData Cache™ application has been designed to provide different levels of authenticated access based on user credentials, e.g., state employees could be given access to see more data than the general public. The data is also encrypted in transit and at rest, which ensures the data can be accessed only by the authorized users. Sanborn GeoData Cache™ has a sophisticated backend dashboard that allows administrators to create/remove users, grant users privileges (such as admin rights), reset passwords, and monitor user history.

Sanborn Lidar Web-Viewer™

Sanborn Lidar Web-Viewer™ allows end users to view and manipulate the datasets hosted on Sanborn GeoData Cache™, and the platform supports all the typical lidar deliverable formats. It allows elevation profiling; area, height and volume measurements; and point density calculations. Users can even change the point cloud display based on the elevation, intensity, RGB or classification.

Vector layers (point, polyline or polygon shapefiles/geodatabases) can be overlaid on the lidar data to allow users to compare the alignment of the vector data relative to the lidar datasets, manipulate the point cloud in 3D, or annotate individual points or features. Standard deliverable products such as DEM or Intensity Rasters can also be shown in the web-application viewer. The end user is then able to download the data of interest (including any applied analytics or manipulations), or stream a raster version of the data (served as a WMS/WMTS) for later consumption in any OGC-compliant software.

Summary

The native lidar format files (LAS) are just one of the many deliverables that are part of a typical lidar project delivery. There are other deliverables as well such as DEM files, vector layers, intensity images, ortho-imagery (in some cases), metadata, survey files, etc. Sanborn GeoData Cache™ can ingest all these file formats for storage and distribution, and Sanborn Lidar Web-Viewer™ can support the same lidar data file formats for viewing, analysis, and manipulation. Together, the system can also serve as a quality control engine for the lidar deliverables, where the quality controller can flag specific issues in the lidar data that can be then addressed by the vendor.

The combined solution of the Sanborn GeoData Cache™ and the Sanborn Lidar Web-Viewer™ offers the following advantages to the end user:

- No need for different plugins
- No need for a powerful Desktop/ Workstation, nor specialized software
- No need for large local storage
- No need for diverse feature extraction tools

With the advent of new generation lidar sensors, the appetite for denser lidar datasets is increasing exponentially. This trend will significantly increase the data storage needs and the band-width requirements for data dissemination. In light of this trend, solutions such as Sanborn GeoData Cache™ and Sanborn Lidar Web-Viewer™ allow for greater capacity for handling multiple, large datasets. The challenges involved in implementing such a solution along with few examples of recommended best practices will be discussed in Part 2 of this article series.

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Dr. Sharad Oberoi leads Sanborn's software development, IT and 3D visualization teams. He has more than 6 years of progressive expertise in the design of robotic mobile mapping systems, decision support systems and the implementation of new technologies to improve end user productivity. Dr. Oberoi holds a PhD from Carnegie Mellon University, and Masters degrees from The University of Chicago and Carnegie Mellon University. He is also a Google Cloud Certified Professional Cloud Architect.

Dr. Srini Dharmapuri, CP, CMS, PMP is with Sanborn Map Company in Pittsburgh, Pennsylvania as VP/Chief Scientist. Dr. Dharmapuri has Master of Science (Physics), Master of Technology (Remote Sensing), and Doctorate (Satellite Photogrammetry) degrees with more than 30+ years of wide-ranging experience within the Geospatial Industry, most notably with lidar, Photogrammetry, GIS and UAS.

SureStar Lidar

Chinese player excels in lightweight sensors

BY CLAIRE ZHANG

Figure 1: Dr. Jane Zhang, co-founder and CEO of SureStar.

Figure 2: Darsi Zhang, co-founder and CTO of SureStar.

Beijing SureStar Technology Co. Ltd. is headquartered in the northwest corner of Beijing, where you can find many high-tech heavyweights, such as Huawei, Baidu, Tencent, Lenovo and Didi. It is a palace of robust innovation and called China's Silicon Valley.

SureStar was found by Darsi (**Figure 1**) and Zhiwu (Jane) Zhang (**Figure 2**) in 2005, on return from their studies overseas, initially to offer lidar mapping solutions for terrain surveying, power-line inspection and railway clearance monitoring. Darsi Zhang, co-founder and CTO, has over 18 years' experience in lidar research and development. Before focusing on lidar technology, he worked for K&S, which is a leading provider of semiconductor packaging and electronic assembly solutions. Thanks to his

Figure 5: Timeline of SureStar product introductions.

experience in the semiconductor industry, SureStar is one of earliest lidar manufacturers to be involved in integrated-circuit design specifically for lidar signal processing (LSP). The high-performance LSP chips, modular design and unique semiconductor assembly process make SureStar stand out in product performance, low weight, and low power consumption, as well as high production efficiency. For example, the 32-beam R-Fans-32 scanner (**Figure 3**) weighs only 738 g, yet is able to detect objects with 10% reflectivity at 200 m. The range of the A-Pilot airborne scanner (**Figure 4**) is as much as 1350 m at 10% reflectivity with a scanner weight of only 3500 g. A timeline of SureStar's product introductions is given in **Figure 5**.

Figure 3: R-Fans-32 scanner.

SureStar co-founder and CEO, Jane Zhang, earned her Ph.D from the University of Guelph. As early as 2014, perceiving a flourish of autonomous vehicle and UAV applications, she decided to put more effort on to the development of automotive lidar and lightweight UAV-lidar. Since launching the R-Fans multi-beam lidar in 2016, SureStar has marketed the semi-flash lidar C-Fans-32 and C-Fans-128, which can be embedded into vehicles. The weight of the Genius UAV-lidar system (**Figure 6**), including laser scanner, IMU, GNSS, control unit, data storage and integration box, is only 1168 g, suitable for installation in most lightweight drones.

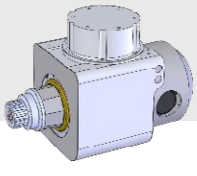
Figure 4: A-Pilot airborne scanner.

SureStar embraces complete and comprehensive lidar core technologies and has reported over 100 intellectual property rights (patents, software copyrights and trademarks). Quick roll-out of new products comes from a talented and fast-growing R&D team. SureStar has its headquarters and R&D

Figure 6: Genius UAV lidar installed on DJI 210.

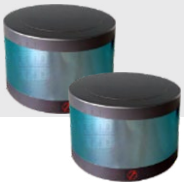
2015

E+RA power inspection pod



2016

R-Fans-16/ R-Fans-32 multibeam lidar



2017

Sky-lark UAV-lidar

2018

Genius UAV-lidar

C-Fans-128 automotive lidar

2019

C-Fans-32 automotive lidar

Figure 7: SureStar's headquarters in Beijing.

center in Beijing (**figure 7**), production facilities in Suzhou, and software team in Hefei respectively. 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 (**Figure 8**). 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 (**Figure 9**). Just as this article was going to press, 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.

Claire Zhang is assistant to the CEO at SureStar. She holds a masters degree in economics from the University of International Business and Economics in Beijing. She focuses on overseas marketing in SureStar and has been engaged in promoting SureStar lidar to global users.

Figure 8: Cargo delivery robots of JD.

Figure 9: 5G autonomous car of Malaysia equipped with SureStar lidar.

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New production facility in Horn, Austria.

RIEGL Invests in New Office and Production Facilities

New, additional facility expansions at the headquarters in Austria as well as a new facility in the United States.

RIEGL, an internationally successful manufacturer of LiDAR scanners for surveying applications headquartered in Horn, Austria, is investing heavily in the expansion of production and office space. The continued, worldwide demand for the high-performance sensors allows the company to grow and expand further.

RIEGL, which celebrated its 40th anniversary last year, is now meeting the rapidly increasing international demand for *RIEGL* laser scanners with office and production facilities expansions.

This summer, a new office and production facility has started construction at the location of the company's headquarters in Horn, Austria. The new building will house the company's printed circuit board production and the software development team. The additional area comprises more than 2200m2 (24,000 sq foot) on three floors and will offer space for up to 80 employees. A state-of-the-art measuring tunnel system with a length of over 100 meters will also be built and be used for testing and calibrating the *RIEGL* sensors. The buildings will be ready for occupancy in fall of 2020.

RIEGL is also continuing to grow in the United States. The company has been active and successful in this market for more than 25 years and is currently building a new North American office facility in Winter Garden, Orlando, Florida, offering 1500m2 (16,000 sq foot) floor space. The building will offer trendy and modern workplaces for up to 50 employees. In addition to office space, the new *RIEGL* USA Headquarters will also allow the company to expand in the areas of support, service and calibration for the complete *RIEGL* portfolio. The building will be ready for occupancy Fall of 2020.

Throughout the building process, state of the art *RIEGL* technology like the *RIEGL* VZ-400i Terrestrial Laser Scanner as well as VUX-based LiDAR mapping drones will be applied regularly to support, monitor, and document the construction processes.

In total, the investment volume for the expansion of the company's facilities in 2019 and 2020 is more than 10 million EUR.

"Our investments in Austria and the US prove our path of success and the growing internationality of the company" explained Dr. Johannes Riegl, founder and CEO of the *RIEGL* Group, and his son, Johannes Riegl Jr., member of the management board and President of the US division of the company.

RIEGL—a privately-owned company with subsidiaries in the US, Japan, China and Australia—has grown continuously over the past years. In the last fiscal year, *RIEGL* achieved a record group turnover of more than 80 million EUR with 250 employees worldwide.

RIEGL is an international leading provider of cutting-edge technology in airborne, mobile, terrestrial, industrial and unmanned laser scanning solutions. RIEGL has been producing LiDAR systems commercially for more than 40 years and focuses on pulsed time-of-flight laser radar technology in multiple wavelengths. From the first inquiry, to purchase and integration of the system, as well as training and support, RIEGL maintains an outstanding history of reliability and support to their customers. Worldwide sales, training, support and services are delivered from RIEGL's headquarters in Austria, main offices in the USA, Japan, China, and Australia and by a worldwide network of representatives covering Europe, North and South America, Asia, Australia, and Africa. For more information, please visit riegl.com

Future RIEGL USA North America Office in Orlando, Florida, USA.

Woolpert First Provider Approved by PennDOT to Operate Drones for State Projects

The Pennsylvania Department of Transportation requires UAS operators to undergo extensive PennDOT training in addition to attaining the FAA's Part 107 Remote Pilot Certificate.

Harrisburg, Pa. (July 9, 2019) — Woolpert had numerous surveying, mapping and geospatial professionals complete the Pennsylvania Department of Transportation's (PennDOT) Unmanned Aircraft System (UAS) training July 2. The training is part of PennDOT's certification process, along with attaining a Part 107 Remote Pilot Certificate through the Federal Aviation Administration (FAA), for contractors who use drones on state projects. Woolpert became the first provider approved.

Woolpert Chief Scientist Qassim Abdullah, Geospatial Practice Leader Tom Ruschkewicz and UAS Technology Manager Aaron Lawrence were among those who attended the training. Lawrence, who was one of the first in the country to earn his Part 107 license in 2016, is now a certified PennDOT UAS operator.

Abdullah, a certified photogrammetrist and licensed professional surveyor and mapper, is an adjunct professor at Penn State University who has taught multiple courses on UAS capabilities. Ruschkewicz has decades of transportation surveying and geospatial experience and is very active in the state of Pennsylvania.

"As we continue to enhance our service offerings in Pennsylvania, we found the training extremely valuable in gaining a better understanding of how PennDOT wants to use UAS and the expectations they have for safe and successful operations," Ruschkewicz said.

"Woolpert is leading the way within the geospatial industry for best practices and product quality assurance when it comes to using UAS for PennDOT and other transportation agencies," added Abdullah, who also has written several articles on bridging the gap between the professional mapping community and UAS operators.

Lawrence said this certification is an example of the multiple state and national efforts underway to safely integrate UAS into national airspace. It also illustrates the variety of measures being taken by individual state agencies to ensure UAS safety for third-party operators, workers and the public.

"The commercial use of drones is moving in the right direction, as evidenced by the many required UAS qualifications," Lawrence said. "We hope to see these safety and proficiency standards become universal; however, it is important to understand that each state has its own regional and environmental concerns. In the meantime, we at Woolpert will continue to ensure our staff is proficient in UAS applications in general and in those specific to each agency's needs. It's what we do."

> "The commercial use of drones is moving in the right direction, as evidenced by the many required UAS qualifications."

Woolpert was the first surveying and mapping firm to be approved by the FAA to fly UAS commercially in designated airspace through its Section 333 exemption in 2014. Since then, the international architecture, engineering and geospatial (AEG) firm has supported a wide variety of projects utilizing UAS, has invested in numerous UAS platforms and employs 18 FAA Part 107 certified pilots.

Woolpert is committed to a vision to become the premier architecture, engineering and geospatial (AEG) firm, and one of the best companies in the country. It's a vision we've been fine-tuning for decades. It guides our decisions and investments, provides our clients with optimal solutions, and offers our employees unrivaled opportunities. Woolpert is recognized as a Great Place to Work by its employees and is America's fastest growing AEG firm. With more than a century of experience, close to 1,000 employees and 30 offices, Woolpert supports public, private, federal, and military clients nationally and around the globe. For more information, visit woolpert.com and connect with us on LinkedIn, Twitter and Facebook.

GeoCue Introduces True View, The Industry's First Drone Lidar/Imagery Fusion Sensor

Nashville, TN – GeoCue Group Inc. unveiled its new True View™ line of drone sensors at an invitation only industry event on June 25th in Nashville, Tennessee. 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.

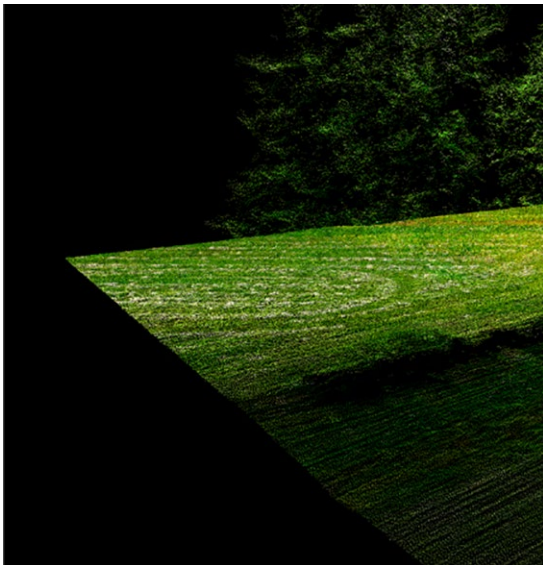
In addition to a complete system presentation and software demonstrations by GeoCue, guest speakers included:

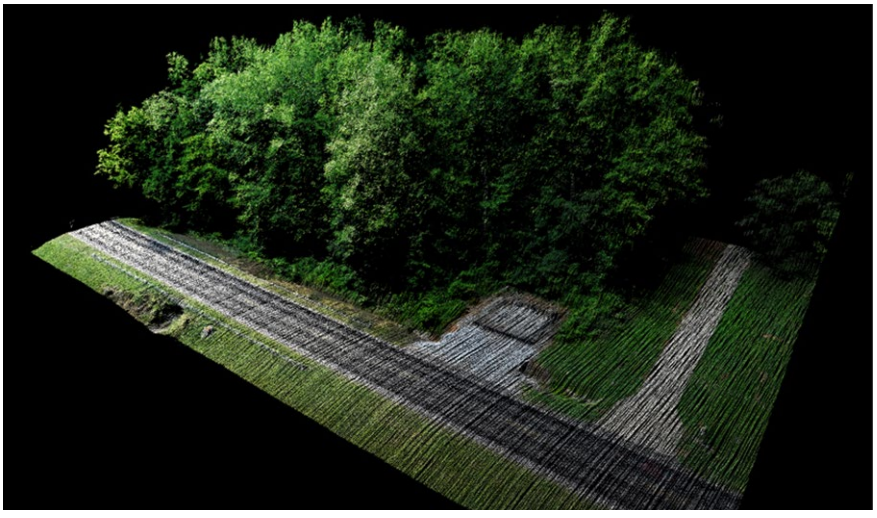
- Lori Eversull of Vulcan Material Corporation, presenting an engaging discussion of how drone sensor technology is used in Vulcan's mining operations.
- Srdjan Sobol, Development Manager for Applanix (a Trimble company), presented the three Applanix/Trimble positioning solutions offered by True View's local or cloud-based positional post-processing workflows.
- Andreas Ploier, CEO of Drone Rescue Systems, discussed the new partnership with GeoCue and the value of a rescue parachute when operating in environments with persons as well as protecting high value payloads.
- My-Linh Truong, UAS segment manager for Riegl, who discussed the new Riegl partnership with GeoCue and the characteristics of the upcoming True View 610's Riegl miniVUX sensor.
- Tyler Crawford of MFE Insurance Brokerage who provided an overview of insuring drones and drone sensors.

Press coverage was provided by Mr. Allen Cheves and Dr. Stewart Walker of *LIDAR Magazine*.

The first sensor of the product line, the True View 410, was displayed at the reveal along with full workflow processing in the companion True View Evo processing software. 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.

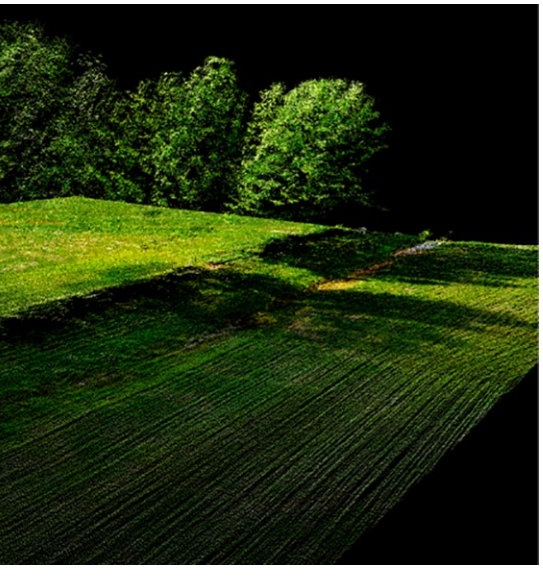
Demonstrations of True View Evo full post-processing workflow software (included with the sensor) were provided. The audience witnessed the creation of stunning 3D





colorized point clouds with processing time from sensor to final product of less than 15 minutes for a 50-acre site. The visualization of colorized vertical surfaces demonstrated the value of the dual oblique cameras and true 3D mapping of LIDAR points to images.

"Anyone considering a drone LIDAR system should pause and evaluate the True View product line," said Lewis Graham, President and CTO of GeoCue. "The True View sensor fusion systems will make 3D colorized point clouds a standard product demanded by customers of high accuracy drone mapping. The 3D colorization approach that we use in our Evo software provides a new level of intelligence in LIDAR point clouds. An advance in sensor technology comes along every few years that changes our industry – True View is one of those instances."



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. For as little as $3,000 per month, a user can obtain an *Evergreen* True View 410 with complete processing software. The minimum time commitment for an Evergreen subscription is 3 months. The base subscription includes enough processing minutes to complete about 20 projects of 50 acres each. Additional processing is purchased by the minute. Both traditional purchase and Evergreen customers can access Applanix SmartBase and Trimble PP-RTX on a per-minute basis (via True View Evo) without the need to commit to an annual Trimble service subscription; all billing is managed by GeoCue.

The True View 410 beta program begins in July with customer shipments to follow. Contact GeoCue at 1-256-461-8289 or info@geocue.com for detailed system information.

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. In 2014, GeoCue Group started a division focused on using small Unmanned Aerial Systems for high accuracy mapping. 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. To learn more, visit geocue.com.

Cepton Names T. R. Ramachandran as Executive Vice President of Marketing

Twenty-year industry veteran will lead Cepton's global product and corporate marketing

San Jose, Calif.–Cepton Technologies, Inc., a provider of 3D lidar solutions for transport, automotive, IoT, industrial, security and mapping applications, today announced the appointment of Dr. T. R. Ramachandran as Executive Vice President of Marketing. Reporting to Dr. Jun Pei, Cepton's co-founder and CEO, Ramachandran will be responsible for managing product and corporate marketing activities, and driving the company's continued leadership in the lidar industry.

Dr. Pei said: "T. R. Ramachandran is a seasoned technology executive with a deep background in marketing and new product introduction and has extensive experience in lidar. We are delighted to have him join our team. His experience working with the world's top automotive OEMs and Tier 1s to introduce advanced lidar technology, along with his strong ability to drive product quality at high volumes, will be instrumental in enabling Cepton's growth in the coming years. He will also apply his considerable financial acumen in partnership with Cepton's CFO Bob Brown to fuel the next phase of our business growth. I look forward to working alongside him and welcome him to the team."

Ramachandran joins Cepton from Velodyne Lidar, where he was Vice President of Product Management and developed a keen understanding of various applications for lidar, including autonomous vehicles and robots, mapping, security, industrial, IoT devices and more. He is a Silicon Valley veteran with strong experience both in innovative startups and larger companies. Among his prior roles, he was Vice President of Corporate Quality and Programs at LSI (now Broadcom), where he played a key role in the transformation of LSI into a $2.5B company and worked with the executive leadership team to pave the way for LSI's acquisition by Broadcom (Avago) for $6.6B.

"Lidar is going to revolutionize the world across a variety of everyday applications. My top priority is to help Cepton become the lidar market leader, drive scalable growth and deliver affordable, high performance and superior quality lidar at large volumes to the world's top automotive Tier 1s and OEMs," said Ramachandran. "I echo our CFO's observation that Cepton has developed a unique technology that will deliver the combination of performance, reliability and cost required for lidar to achieve mass adoption across a variety of industries. I have personally been impressed by the progressive and visionary leadership of Cepton's CEO, Dr. Jun Pei, who combines path-breaking innovation, a strong customer focus and dedication to making lidar widely available and broadly affordable. I am excited by the opportunity to work with him and his experienced team to make Cepton successful."

Cepton Technologies, Inc. is a 3D sensing solutions provider shipping state-of-the-art lidar products for the automotive, security, transport infrastructure, industrial, IoT and mapping markets. Founded in 2016 and led by industry veterans with deep experience in lidar and advanced imaging, Cepton is focused on the mass market commercialization of high performance, high quality lidar solutions for the automotive industry and beyond. Cepton's patented lidar technology delivers outstanding detection range and resolution, reliability and affordability, to enable perception for the fast-growing market for autonomous and smart machines. For more information, visit: cepton.com

Graham, *continued from page 48*
relationship between bias, mean error and variance that needs to be considered when thinking about error analysis:

$$RMSE^2 = MSE = \bar{r}^2 + s_r^2$$

where MSE is the Mean Square Error and:
$\bar{r}^2$ = the mean of the residuals, squared
s_r^2 = the square of the sample standard deviation (the sample variance) of the residuals

In our data set, we could significantly improve the RMSE if we shifted all the data by the mean of -5.0 cm. This is frequently performed by LIDAR processing technicians and is popularly referred to as a "Z bump." But is this a legitimate operation? My suggestion is that we use our idea of how certain we are of the mean to make this decision. This certainty can be obtained by examining the Standard Deviation of the Mean (SDOM):

$$\text{SDOM} = \frac{s_r}{\sqrt{N}}$$

where S_r is the standard deviation of the residuals and N is the number of check points

I argue that if $|\bar{r}|$ – SDOM > 0 then debiasing is legitimate. This is saying that if the uncertainty in the mean is small relative to the mean itself, we can shift the mean. For our example, the sample standard deviation is 2.74 cm (I get this by rearraigning the equation for RMSE). The number of check points that have been used, N, is 17. This gives an SDOM of 0.66 cm. This is well outside of our mean error of -5.0 cm so I can apply the "Z bump." Once I shift the data (using a LAS shift tool in True View Evo or LP360) and recompute the

Vertical	
Mean Error:	-0.000
Error Min, Max:	[-0.038, 0.050]
Error Range:	0.088
Skew:	0.066
RMSE:	0.027
ASPRS Accuracy Class:	0.027
Min Contour Interval:	0.081

Figure 2: Error after "Z bump"

residual error, I obtain the results of **Figure 2**.

Note that, as expected, the new mean is zero. If it is not, then I made a mistake! The error range remains, of course, unchanged. But the new RMSE is now 2.7 cm. This has significantly improved the accuracy quality of these data, at least according to the way we measure accuracy using the new ASPRS accuracy specifications.

I think, until someone raises a mathematically sound objection, that the SDOM test is a justification for performing the Z bump. Now a physicist would say "This is a systematic error. You need to find the root cause of this error and correct it." I consider myself a student of physics and completely agree with this stance. However, we often do not have enough information about the internals of the laser scanning systems we use to make this determination. I am sure others will argue that maybe we need to use 2 × SDOM or some other factor. That is a good debate to have.

I intend to write a more detailed white paper on this topic and publish to our web site. Till then, I think this is a start. This should make you feel better about doing the Z bump while your parents are watching.

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.

Let's all do the Z bump!

I just returned from the summer meeting of the Transportation Research Board's AFB-80 committee. This is a standing committee that deals with high accuracy geospatial data acquisition for transportation applications. We always have a lot of very interesting presentations at this conference but seldom big surprises. This year was an exception when (gasp!) Dr. Michael Dennis of NGS announced that the US Survey foot will be deprecated when the new 2022 spatial reference system comes online. There was a bit of banter that, in the current political climate, we might have to rename the International Foot the "American Freedom Foot…" I pleaded that we just jump to the metric system but, sadly, that is not going to happen.

I often leave bits of unfinished business in my wake. Looking back on some previous Random Points columns, I noticed that justification for vertical "debiasing" of LIDAR data is one of those dangling items. I made a statement that, under certain circumstances, we can shift the vertical of a point cloud. Let's make up a rule for this.

I have done a small amount of research on this topic (meaning I typed it in to Google) with no satisfying results. Thus I will just develop my own guidance on this and see what kind of complaints are forthcoming.

Consider the data set of **Figure 1** flown at our test range ("The Shop"). This is a LIDAR data set from a GeoCue True View 410, colorized by the integral oblique cameras. The True View 410 uses a Quanergy M8 Ultra laser scanner. This is an 8-beam scanner with a total pulse repetition rate of 420 KHz. Note the check points set out over the test area. There are 21 total check points in this particular project. I have eliminated 4 of these. One is the base station and should always be eliminated since the tripod and antenna inject vertical "noise." The other three were eliminated because the targets were missing. There are several others I would like to eliminate because it would make the statistics better. This brings us to the first rule of measuring accuracy; you cannot eliminate a check point from the data set without a justifiable reason. Bad accuracy is not one of those reasons! After eliminating the base and the three missing targets, I observe a Root Mean Square Error (RMSE) of 5.7 cm. This is actually quite good considering the fact that this is positioning without the introduction of ground control. The mean error is -5.0 cm and a total error range is 8.8 cm

Figure 1: True View 410 Test Data Set

Now recall from a 2017 Random Points column (I am inferring the "i" subscript for each point):

$$RMSE_Z = \sqrt{\frac{\sum_{i=1}^{N}(r_z)^2}{N}}$$

where
r_z is the vertical (z) residual
N is the number of test (check) points

We do this square root of the residuals squared trick because we do not want negative residuals canceling positive ones. There is an incredibly important but sometimes neglected

continued on page 46

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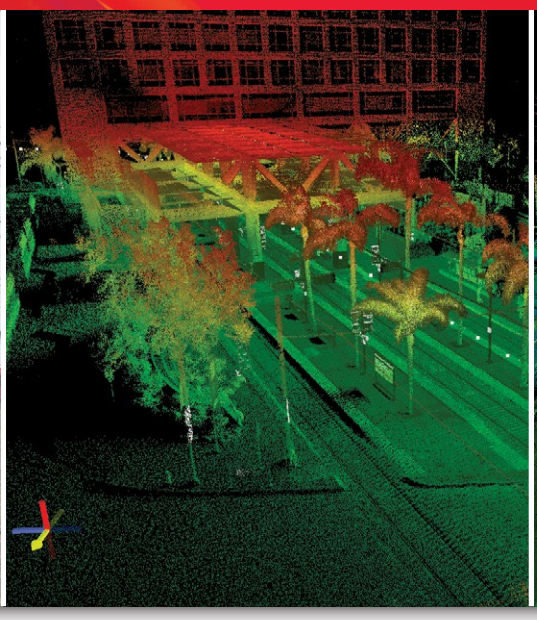

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