VOLUME 13 ISSUE 3

LIDAR MAGAZINE

FALL 2023

SPECIAL ISSUE

SENSOR SPOTLIGHT

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Well into 2023, the pandemic continues to impact the geospatial industry. In 2021 and 2022, supply chains and productivity were disrupted, leading to shortages of critical materials, parts, and products, some of which compromised vital survey hardware. However, our industry has shown resilience as many companies and manufacturers have implemented new workplace safety protocols, increased automation, and diversified supply chains to mitigate the impact of future disruptions. In addition, geospatial hardware manufacturers have continued to advance new and unique capabilities for data acquisition.
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In the realm of filmmaking and television, 3D laser scanning is increasingly utilized to bring physically impossible worlds and captivating stories to life. Visual effects (VFX) specialists use a technique called Matchmove to generate effects, seamlessly blending live-action footage and realistic computer-generated imagery (CGI). Laser scanning enhances this process, creating evermore immersive worlds and visuals for audiences worldwide. One pioneering company deploying the power of laser scanning for VFX is South Korea's 75mm Studio Co., Ltd1. (75mm).
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Woolpert collected lidar data of this Wyoming canyon in Yellowstone National Park to create a digital elevation model for the U.S. Geological Survey. Courtesy of USGS.

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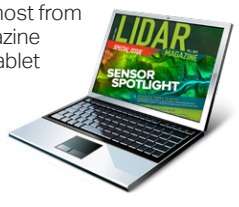

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Model Behavior

The winds of change continue to blow through the lidar industry. In this year's Sensor Integration Spotlight, we've addressed a handful of the most promising integrations of recent.

Kicking things off (page 6), Woolpert's Qassim Abdullah provides his annual review of the "Top Geospatial Trends to Watch in 2023", highlighting the increased use of artificial intelligence (AI) and machine learning (ML) in geospatial applications. Qassim notes that AI and ML are being used to automate tasks, improve data accuracy, and develop new products and services.

3D laser scanning is increasingly being used in the film and television industry to create realistic and immersive worlds. Contributor Megan Hansen (page 26) delves into the ways that Visual effects (VFX) specialists use it to create digital models of real-world objects and environments. These models are then used to generate computer-generated imagery (CGI) that is seamlessly blended with live-action footage. All of this allows the VFX team to create realistic and immersive visuals for various productions.

In Brisbane, Australia (page 36), a digital twin is being used to help plan and construct a new underground railway, offering a virtual representation of the city's infrastructure, including the existing railway network, roads, buildings, and utilities. The system is being used to simulate and optimize the construction process, identify potential risks, and communicate with stakeholders. It is also being used to plan future operations and maintenance of the railway.

Wrapping up our features, Ada Perello highlights lidar coverage in Europe (page 41). While the United States has made significant progress in recent years through its 3D Elevation Program (3DEP), eventually covering 89.5% of the nation with high-resolution, homogeneous, continuous, and accurate elevation data, only 17% of Europe has been covered in this manner. Ada explains how this lack of data is limiting the ability of European countries to use lidar for disaster response, infrastructure planning, and environmental monitoring.

We close this edition with Jason C. Fries latest "Forensic Dimensions" installment. Through his column, Jason continually highlights the ways in which lidar has become foundational to the legal world when it comes to accident reconstruction, video analysis, hydrology and more.

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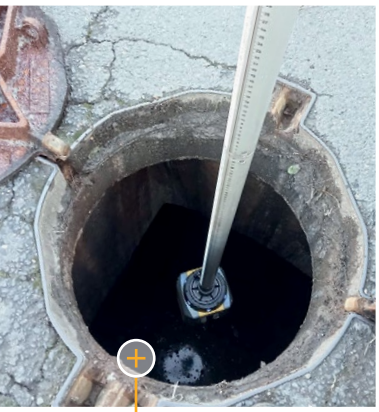

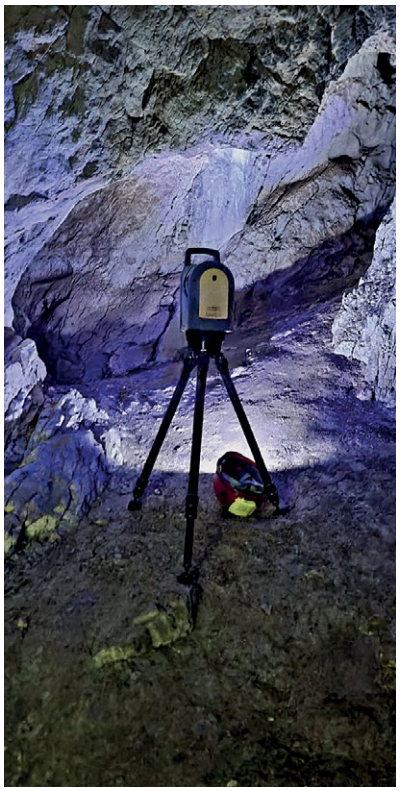

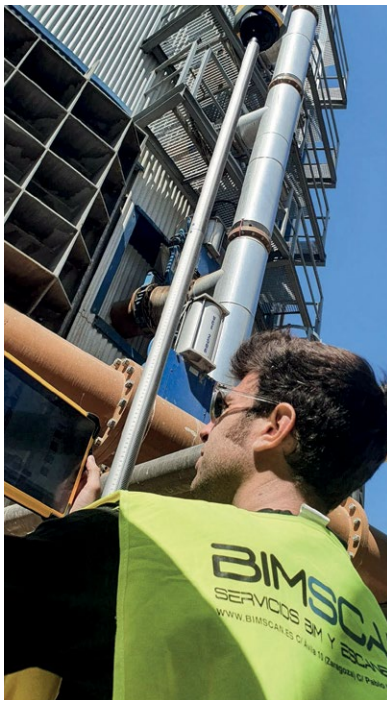

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The geospatial industry can advance the future of safe, autonomous transportation by standardizing high-definition maps for a global road network.
Courtesy of Getty Images.

Top Geospatial Trends to Watch in 2023

And lidar is one of them!

For the last six years, I have been writing this "Top Geospatial Trends" column, which is usually published in January or February. Some years, the columns write themselves, as advancements in the industry emerge or innovative perspectives demand input and conversation. This year, because the industry is still working to shake off the dust from the pandemic, this column is being published in the summer.

For this year's edition, I'll revisit how the trends highlighted last year fared and if they will continue to shape our year ahead, spotlight some things to watch in the last six months of 2023, and provide my perspective about the future of geospatial through the lens of the revised American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Digital Geospatial Data, which are due to be published later this year.

Navigating recovery, gaining strength

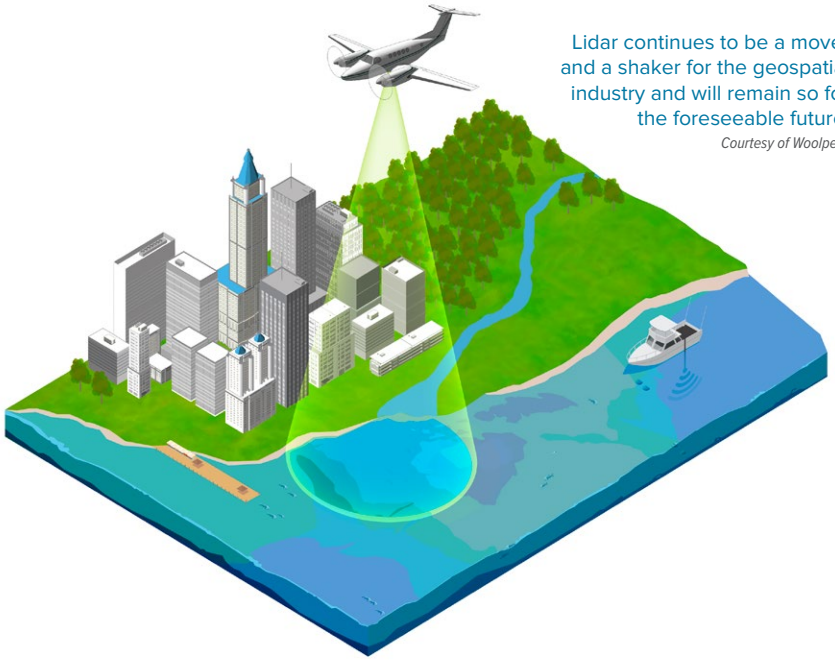
Four months into 2023, the pandemic continues to impact the geospatial industry. In 2021 and 2022, supply chains and productivity were disrupted, leading to shortages of critical materials, parts, and products, some of which compromised vital survey hardware. However, our industry has shown resilience as many companies and

BY QASSIM ABDULLAH

manufacturers have implemented new workplace safety protocols, increased automation, and diversified supply chains to mitigate the impact of future disruptions. In addition, geospatial hardware manufacturers have continued to advance new and unique capabilities for data acquisition.

Digital twin: Last year, I shared how BIM and GIS provide the foundation for the digital twin, and how the nearly synonymous term of "metaverse" was gaining traction. Over the last year, the collective benefits and returns on investment for the digital twin have continued to expand. As the value of the digital twin is increasingly realized, demand for this technology will skyrocket. A digital twin is a digital replica of a physical environment, whether it is an asset, process, highway corridor, river, ocean, or even the Earth. This digital representation comprises the entire life cycle of the asset or the project, from the planning stage to design and construction, and continues through operating the asset—all in one place.

Since the digital twin mimics the real-world characteristics of the physical environment in real time, with the help of Internet of Things (IoT) sensors, a facility engineer can remotely observe the operational environment of a building to manage environmental controls, power consumption, air quality, fire alarm systems, etc. A city emergency response team can simulate disaster scenarios to identify evacuation routes and aid access through a digital twin, or a port authority can manage its assets and port operations, guiding incoming and outgoing ships through its navigation channel by way of precision navigation. This capability can save billions of dollars at commercial ports that have restricted visibility due to fog or other environmental conditions that can impede navigation.

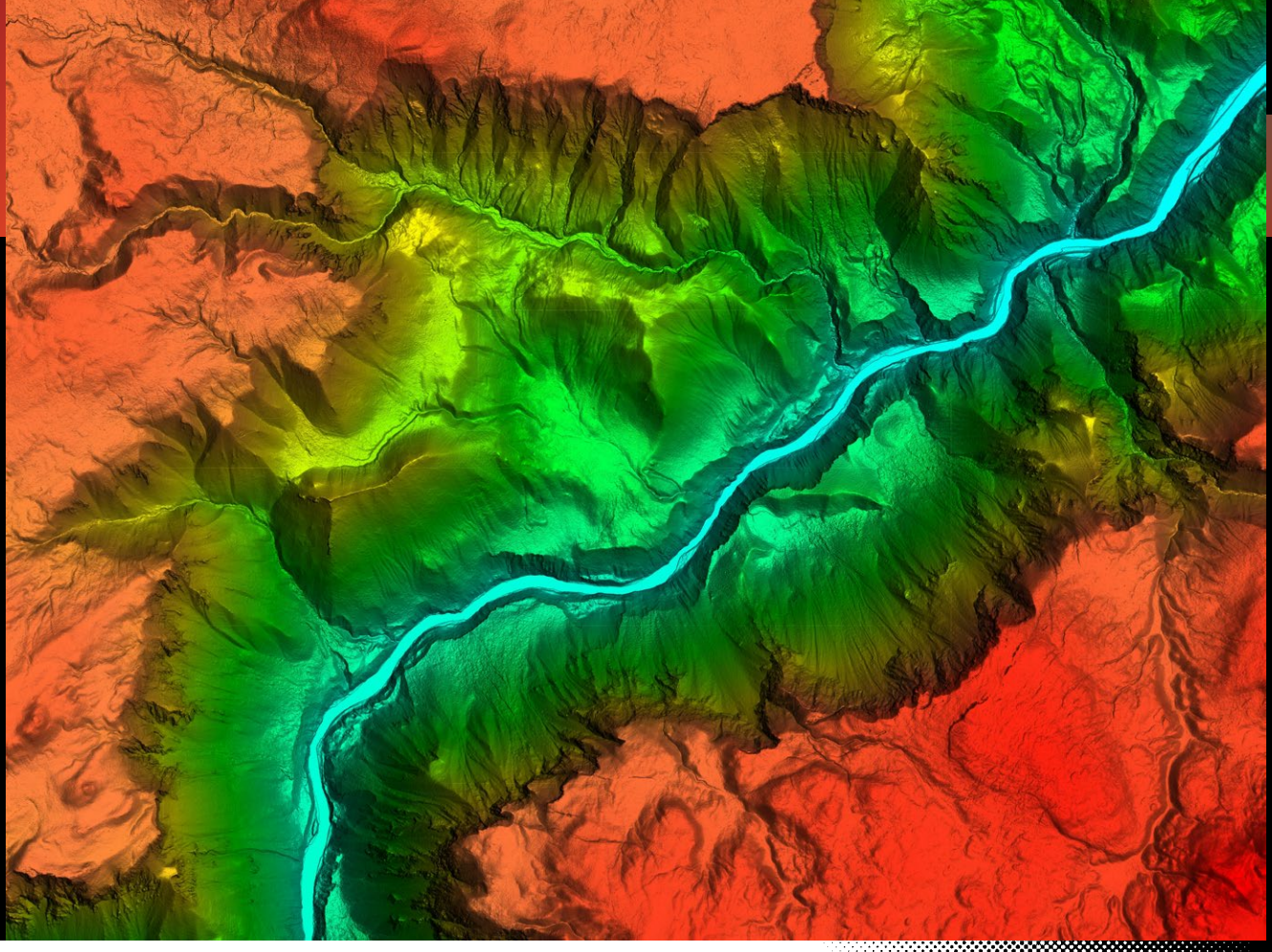


Lidar continues to be a mover and a shaker for the geospatial industry and will remain so for the foreseeable future.
Courtesy of Woolpert.

Additionally, the smart city concept coupled with the IoT will continue to expand, generating a wealth of data and information that can be used for geospatial analysis through artificial intelligence. The digital twin concept is fertile ground for using AI tools to extract useful information and predict future trends and phenomena. Increasingly, software companies are providing platforms for building and hosting digital twins. Companies such as Microsoft, through its Azure digital twin platform, Bentley, Autodesk, and Esri have developed capabilities to support digital twin development.

Virtual collaboration rooms and mixed reality: Several technologies that support virtual collaboration and data visualization were spotlighted in 2022. Those platforms generate the need for 3D data while providing a new means of data modeling and interpretation. These include Microsoft Mesh and HoloLens 2; Bentley's mixed reality platform, SYNCHRO XR; and the NVIDIA Omniverse platform. Demand for higher-resolution 3D geospatial data has grown rapidly in the past year. This will continue to fuel multiverses that interface to human factors through augmented and virtual reality, offering new possibilities for visualization, design, and analysis. This mixed reality tech trend will rotate upward as more applications of AR and VR are discovered and applied to support multiple industries.

Deep into miniaturized sensors: Smartphones continue to branch out geospatially, putting lidar capabilities in the hands of the masses while expanding opportunities for professional surveyors and mappers to conduct geospatial surveys on small projects. A sneak preview of smartphones coming out



Woolpert collected lidar data of this Wyoming canyon in Yellowstone National Park to create a digital elevation model for the U.S. Geological Survey.
Courtesy of USGS.

this year indicates that they will include even more advanced lidar systems. This underscores how sensor systems will continue to get smaller, more efficient, and more technologically advanced.

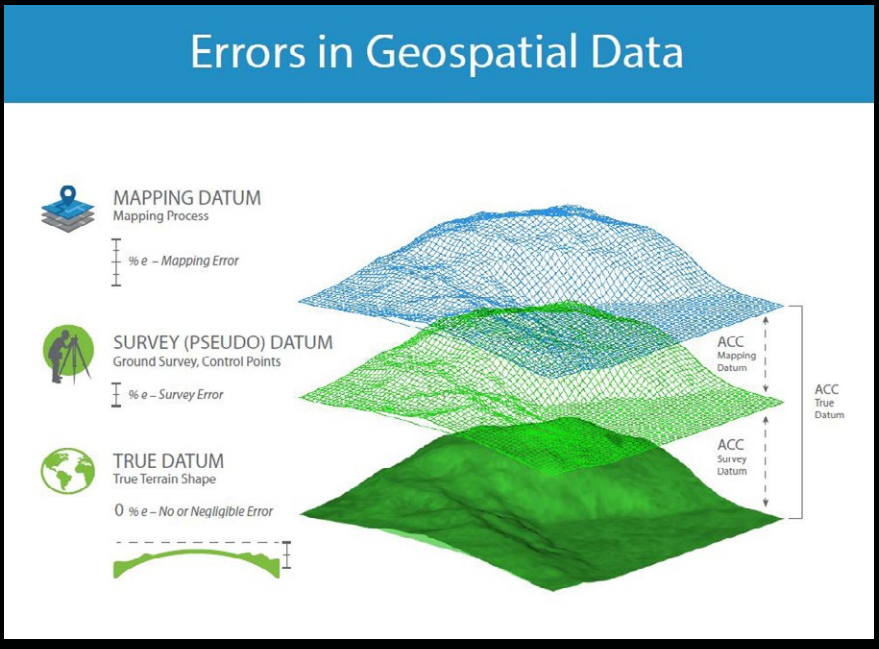
High-definition maps for autonomous driving: I made a plea last year for the geospatial industry to take the lead in creating and standardizing high-definition maps for a global road network in support of autonomous vehicles. Sadly, a year has passed, and the situation remains unaltered. This precision location data should include lane numbers, freeway exit lanes, pedestrian crosswalks, bridges, overpasses, tunnels, locations of traffic control devices, 3D trajectories for road edges and boundaries, etc., with accuracy to the centimeter level, meter-by-meter road grade, and road superelevation. Addressing this situation continues to be an immense opportunity for our industry and the future of safe autonomous transportation.

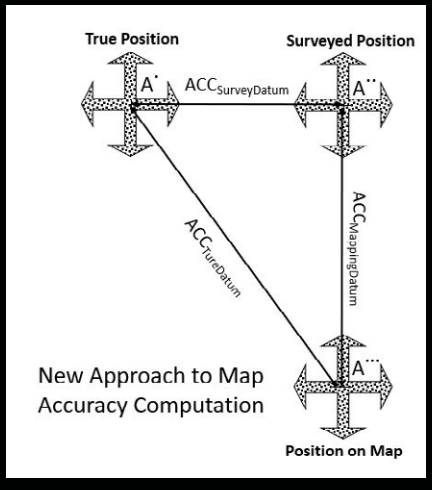
Rising drone demand: As predicted, lidar based on UASs took off in 2022 and will continue to rise, providing a healthy offering of new and affordable lidar. In 2021, growth was spurred by the DJI lidar system, Zenmuse L1, which provided high accuracy at lower cost. Today, while most affordable UAS-lidar systems are based on Livox laser technology, systems based on Hesai technology (or Hesai scanners) are gaining interest, having proved to be more robust and better suited for general survey, mapping, and inspection applications. An example of this is the RESEPI XT32 by Inertial Labs, which features a 360-degree field of view and 32 lasers. The manufacturer claims the RESEPI XT32 provides 1-centimeter accuracy.

For drones overall, the industry demand is strong, especially for mapping and inspection applications.

Whirl around the coastal regions: Coastal wind energy contracts were highlighted in my article last year as part of a larger effort by the U.S. to transition to cleaner, renewable sources of energy and reduce reliance on fossil fuels. In 2022 and into 2023, this effort continues to grow, with wind farms approved and constructed along the nation's coastlines.

On a larger scale, the demand for airborne lidar bathymetric data is on the rise and best demonstrated by the Florida Seafloor Mapping Initiative (FSMI), which is being managed by Florida Department of Environmental Protection, as well as a multitude of projects in the Pacific. These are aimed at collecting critical foundation data needed for coastal inundation





Some of the ideas underlying the second edition of the ASPRS Positional Accuracy Standards for Digital Geospatial Data

modeling, resilience planning and engineering projects.

Data democratization: In the past year we witnessed an explosion in the demand for high-resolution, high-frequency geospatial information from denser point clouds to more crowd-sourced location data. New market entrants are using AI to extract infrastructure features in exquisite detail. The market is hungry for good, raw 3D data to feed these algorithms. With the higher demand for geospatial data, we should see falling prices and more frequent update, i.e. a greater decrease in shelf-life. The quality and availability of publicly available data will also increase.

AI and the cloud: AI and machine learning both play a significant role in geospatial analysis and mapping. Thanks to private sector investments, cloud data hosting and processing, serverless cloud computing, off-the-shelf and open-source technologies, and streamlined workflows with AI tools all continue to trend upward. I am still hoping that federal and public funding can be used to entice further creativity in this field. Without these investments outside the private sector, the most cutting-edge geoanalytics will not be available to the broader market.

Lidar growth: As mentioned in multiple topics above, lidar continues to be a mover and a shaker for the geospatial industry and will remain so for the foreseeable future. Lidar efficiencies continue to expand across other industries to support robotic applications such as autonomous driving and machine learning.

Bathymetric lidar has also been getting more attention. Leica recently announced the release of its newest deep bathymetric lidar sensor, the Leica HawkEye-5, which reportedly has a 25% increase in performance. Woolpert and the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) announced Bathymetric Unmanned Littoral LiDar for Operational GEOINT (BULLDOG) technologies and sensor. These enable the collection of high-resolution topobathymetric data at a higher altitude, resulting in a broader swath than previously developed lidar systems.

The introduction of these new bathymetric lidar capabilities is timely, as they are being employed to serve the many vital statewide and national coastal mapping initiatives, as noted above with initiatives like FSMI. States are using this federal funding window to collect data essential to everything from asset management to infrastructure

planning to disaster response. What is key to these opportunities is that contracting agencies make sure they collect consistent, high-quality data so they can reap the rewards of this funding for years to come. Miniature lidar manufacturing, especially for sensors mounted on drones, is getting a healthy share of the lidar market as more surveying and mapping businesses embrace the technology.

Other noteworthy trends

Here are a few other quick-hitting geospatial trends in technologies and methodologies to watch in 2023:

- Indoor mapping will continue to become more sophisticated, opening the door for improved indoor wayfinding and asset management.
- Location data will be subjected to increasing privacy and security regulations and standards. For the extra layer of security it provides, we may witness increased use of blockchain technology in geospatial data management and sharing.
- With more user-friendly data visualization tools available to all industries, 3D geospatial data will be increasingly used in training, gaming, planning, design, asset management, navigation, and other applications.

ASPRS Accuracy Standards update

When we published the ASPRS Positional Accuracy Standards for Digital Geospatial Data in 2014, we knew we would have to modify it based on user experience and feedback. Sure enough, after eight years of fast-changing sensor technologies and evolving applications, it became clear that significant changes needed to be made to the standards to make them more adaptable to today's mapping practices.

One of the most important changes that our revision working group has endorsed is easing the accuracy of field surveying requirements for ground control and checkpoints. As we generate more accurate products, we have realized that the current accuracy requirement for checkpoints of three times better than the accuracy of the tested product has rendered nearly useless the affordable RTK-GPS techniques that are predominately used for surveying. This requirement has forced contracting agencies to specify more expensive surveying techniques, which has proved to be cost-prohibitive for completing these contracts.

Another important change is the addition of five addenda on best practices and guidelines in project notes and data reporting, photogrammetry, lidar, UAS, and field surveying. When we published the first edition in 2014, we designed it to be a modular standard to accommodate additional materials as the industry evolved. Since then, we have witnessed an unprecedented acceleration in geospatial technologies and practices. This growth necessitated guidelines and best practices in multiple aspects of geospatial mapping to help users of the standards navigate these rapidly changing advances. These addenda were crafted by industry leaders who specialize in these fields.

In addition, an important change is coming regarding the way we evaluate product accuracy. Currently, we ignore the error in survey checkpoints. That practice was acceptable when geospatial mapping product accuracy was low, and the surveying techniques applied did not represent a substantial enough source of error to be considered in computing product accuracy. As we are moving into more accurate products, i.e. in the range of a few centimeters, it has become apparent that the 2 cm error embedded in the RTK-GPS survey technique can no longer be ignored. The new method will consider the fit of the product to the checkpoints plus the error of the survey.

The second edition of these standards will be published in the next few months. A forthcoming article will highlight the changes and their ramifications, which are designed to advance the geospatial industry. Above all else, this will have a long-lasting impact on the industry.

Woolpert Vice President and Chief Scientist **Qassim Abdullah, PhD, PLS, CP,** has more than 40 years of combined industrial, R&D, and academic experience in analytical photogrammetry, digital remote sensing, and civil and surveying engineering. When he's not presenting at geospatial conferences around the world, Abdullah teaches photogrammetry and remote sensing courses at the University of Maryland and Penn State, authors a monthly column for the ASPRS journal *Photogrammetric Engineering & Remote Sensing,* and mentors R&D activities within Woolpert.

This article is running in both *Photogrammetric Engineering & Remote Sensing* and *LIDAR Magazine*.

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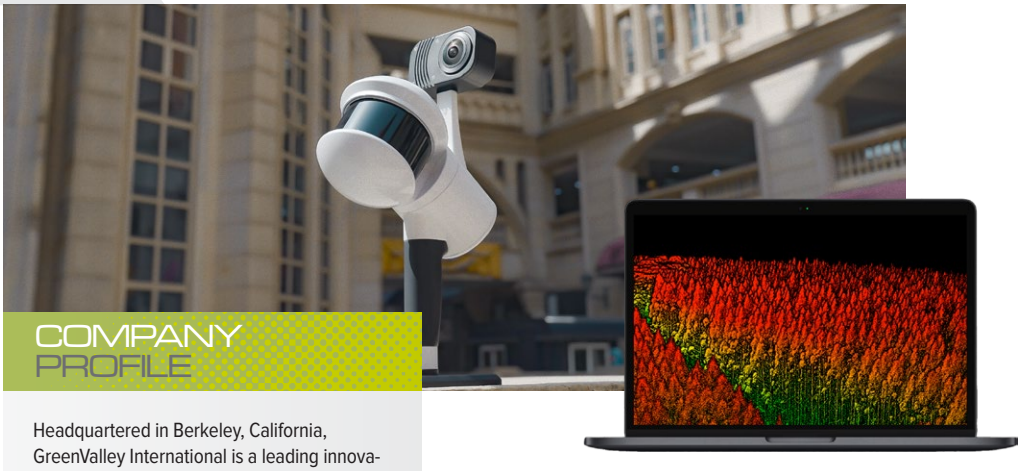

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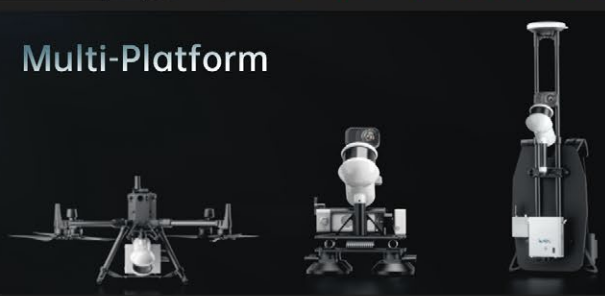

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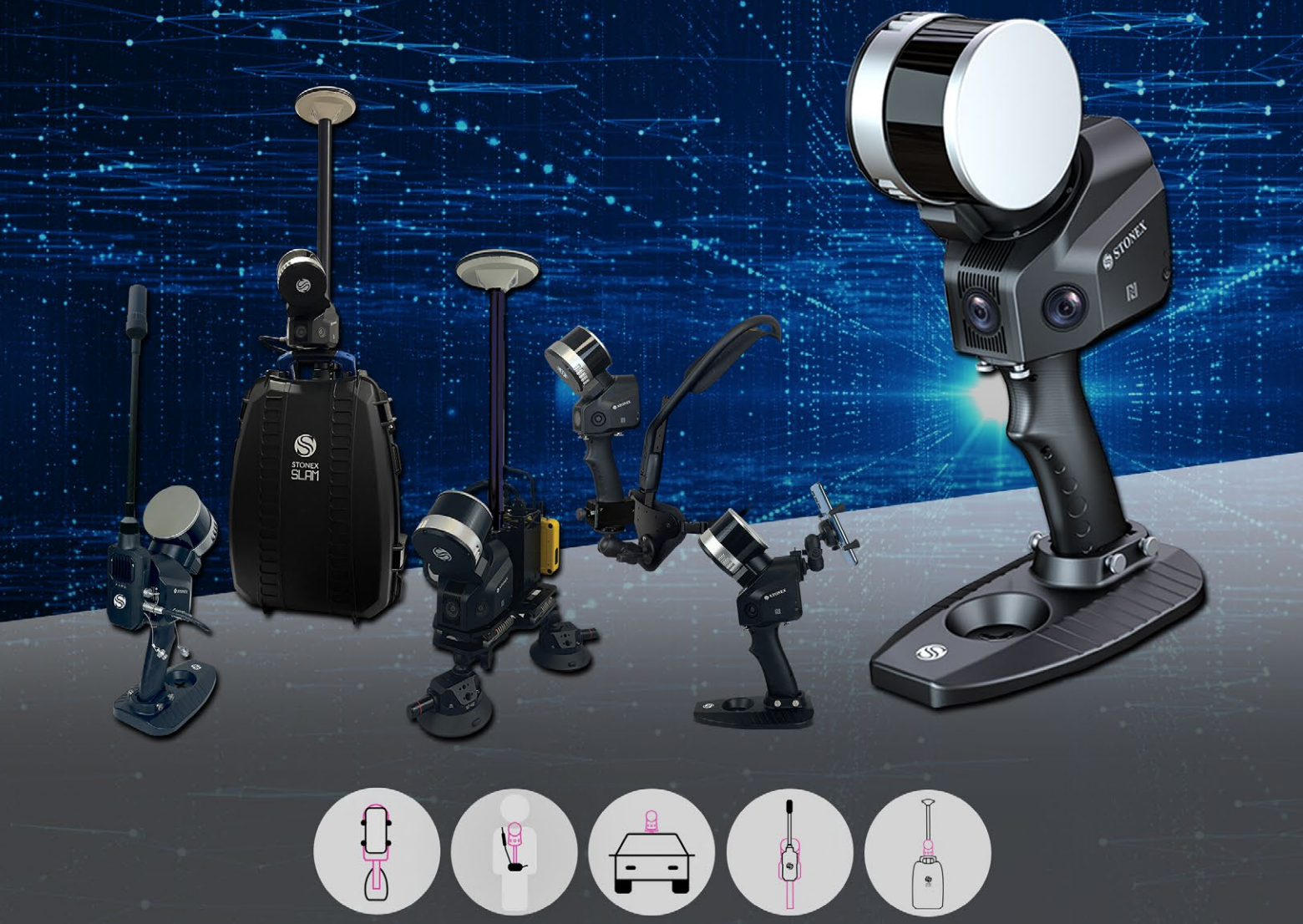

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- UNMANNED/UNCREWED

APX-18 UAV

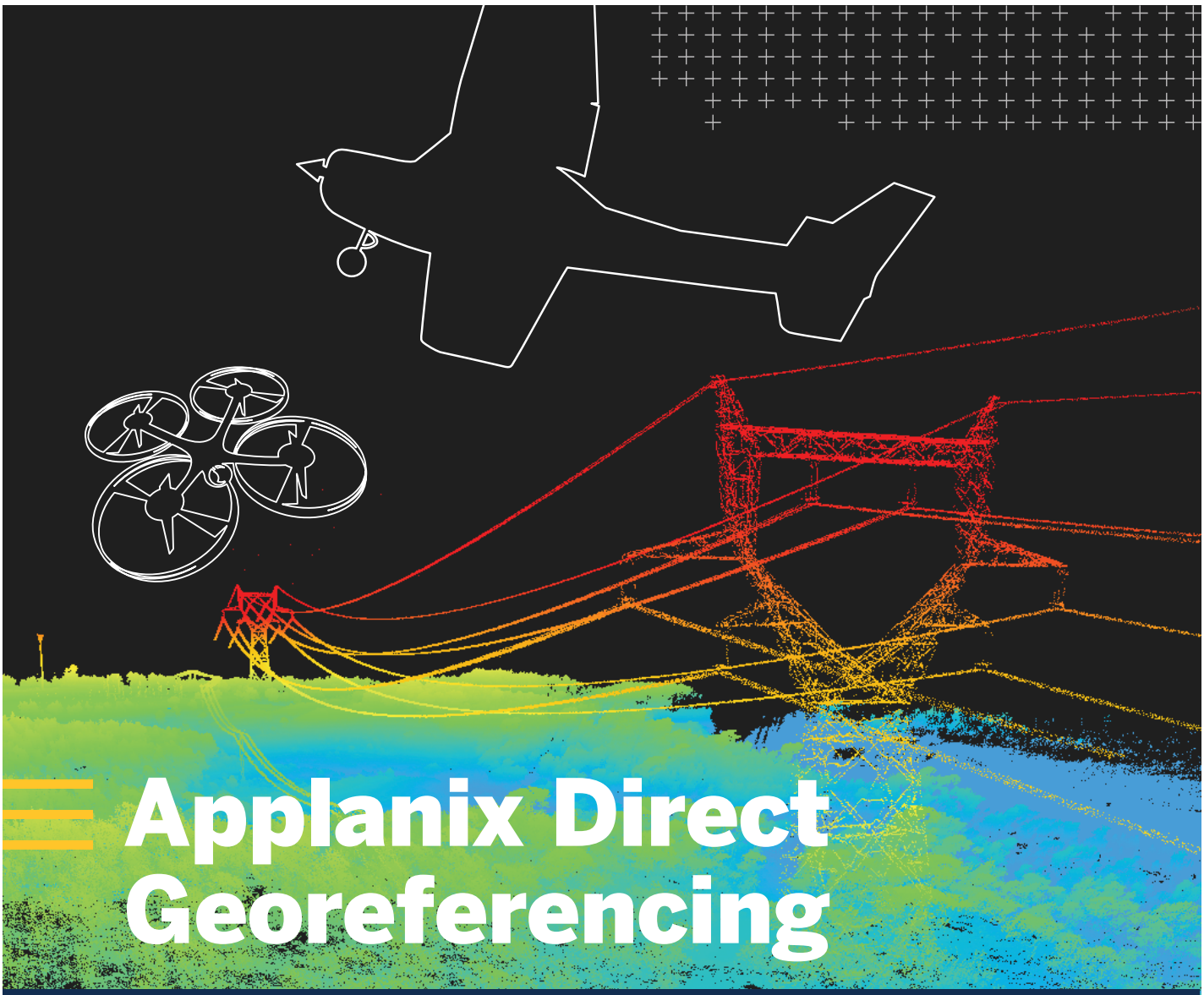
The Trimble APX-18 UAV is an OEM GNSS Inertial solution with dual GNSS antenna input, designed to georeference lidar and other imaging data when collected from Unmanned Aerial Vehicles (UAV) at low speeds or when hovering. Comprised of a small single OEM board containing a precision GNSS receiver with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

High accuracy, extremely small package

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

Key features:

- High-performance Direct Georeferencing solution for improved efficiency and accuracy of mapping from small Unmanned Aerial Vehicles
  - Reduce/eliminate GCP's
  - Reduce sidelap
  - Accurate lidar georeferencing
  - Instant alignment through dual GNSS antenna heading
- Compact single-board OEM module complete with survey-grade multifrequency GNSS receiver and MEMS inertial components
- Applanix IN-Fusion™ GNSS-Inertial and SmartCal™ compensation technology for superior position and orientation performance
- POSPac UAV Differential GNSS Inertial post-processing software for highest accuracy
- RTK real-time position for precision landing applications
- Supports all common RTK corrections such as CMR, CMR+, RTCM



Applanix Direct Georeferencing

Turn your aerial vehicle into a professional mapping solution, no matter what you fly!

- GNSS-inertial technology specifically designed for Direct Georeferencing airborne sensor data without base stations.
- Applanix DG™ is used with cameras, LiDAR, and hyperspectral sensors for highly-efficient, automated mapping and surveying.
- Experience the accuracy of POSPac MMS/POSPac UAV with Trimble CenterPoint® RTX™.
- Discover Applanix IN-Fusion™ GNSS-Inertial and SmartCal™ compensation technology for superior position and orientation performance.

Trimble Applanix
85 Leek Crescent, Richmond Hill, ON L4B 3B3 Canada
T +1-905-709-4600, F +1-905-709-6027
www.applanix.com
airborne@applanix.com

Trimble®

RIEGL

APPLICATIONS

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

COMPANY PROFILE

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

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

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

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

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

riegl.com* | *rieglusa.com

Innovation in 3D

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

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

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

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

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

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

RIEGL UAV
LiDAR SENSORS & SYSTEMS

CHOOSE THE SENSOR EXACTLY RIGHT
FOR YOUR SPECIFIC SURVEYING MISSION!

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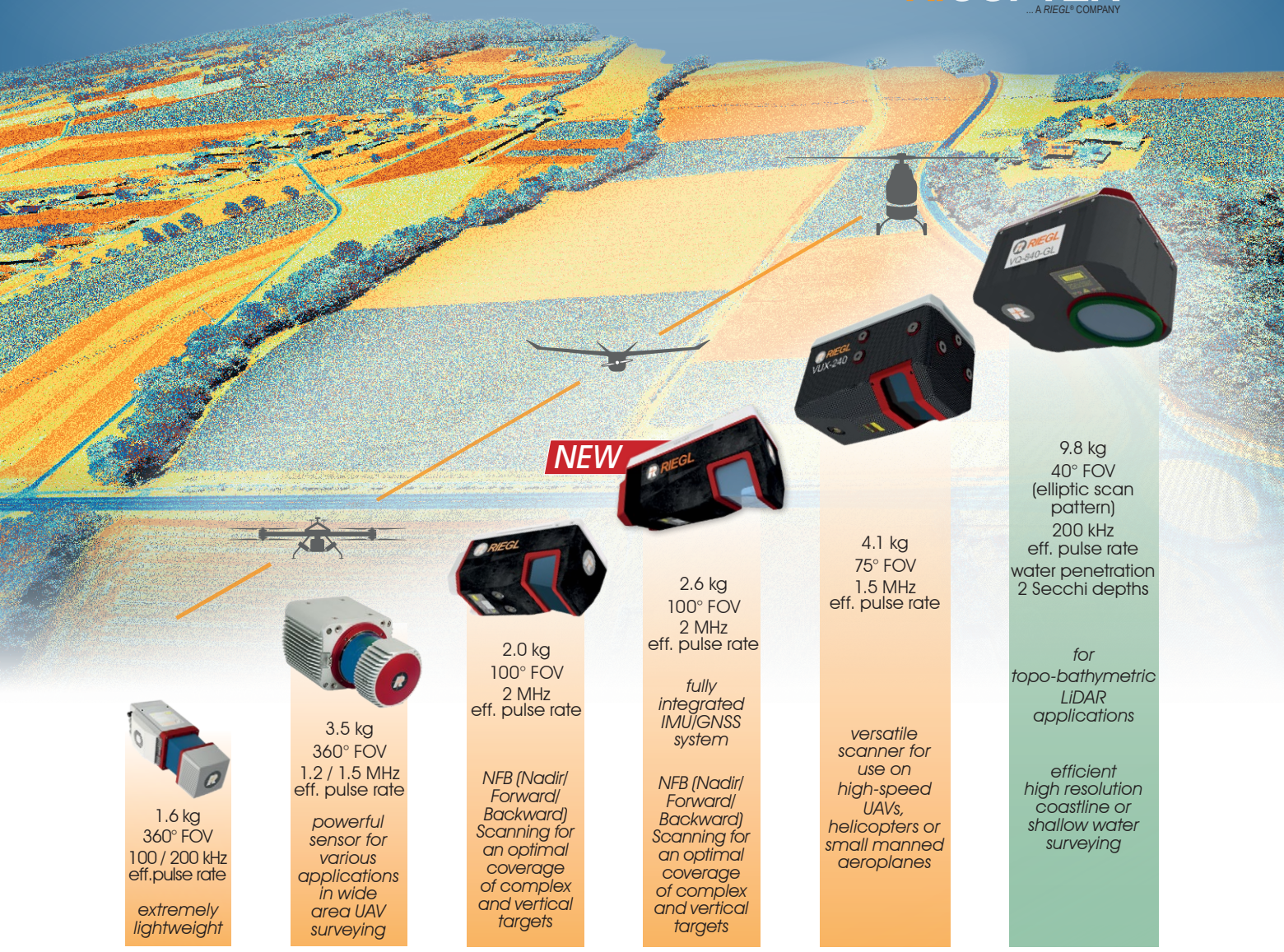


miniVUX-1UAV miniVUX-3UAV	VUX-1UAV[22] VUX-1LR[22]	VUX-120[23]	VUX-160[23]	VUX-240	VQ-840-GL
1.6 kg 360° FOV 100 / 200 kHz eff.pulse rate *extremely lightweight*	3.5 kg 360° FOV 1.2 / 1.5 MHz eff. pulse rate *powerful sensor for various applications in wide area UAV surveying*	2.0 kg 100° FOV 2 MHz eff.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

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

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

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

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

RIEGL®

LIDAR LEADER AWARDS
OUTSTANDING INNOVATION

GEOCUE

COMPANY PROFILE

GeoCue and Microdrones have something for everyone. GeoCue and Microdrones have joined together to offer the very best in drone surveying equipment, geospatial software, workflow, training, and support.

Does your business need only software to process LiDAR data and images? LP360 allows you to process, analyze, and maximize drone survey data, producing valuable information and deliverables.

Are you in need of only software and the LiDAR payload? TrueView offers innovative drone LiDAR and photogrammetry sensors integrated into lightweight payloads compatible with all platforms that can carry the weight.

Or, if you prefer a fully integrated system then our product line from Microdrones offers complete end-to-end systems that include the drone, the LiDAR and imaging payload, software, workflow, training, and support.

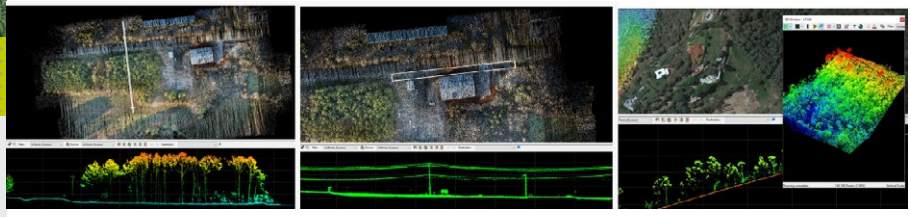
GEOCUE

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

geocue.com

APPLICATIONS

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



True View 3D Imaging Sensors

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

Fly, Process, Deliver—All in One Solution

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

Utility-Grade to Survey-Grade 3D Imaging

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

Drone LIDAR Sensor Subscription Offering

Explore drone LIDAR at low risk and low cost. This unique business model that allows customers to acquire a True View 3DIS under a subscription model for periods as short as ONE MONTH! This is an excellent model for seasonal use and surge capacity.

3D IMAGING SENSORS

Drone LiDAR + Photogrammetry Integration

Data Collection

Collect LiDAR and Photogrammetry in a single flight. TrueView 3DIS can be mounted on any UAV that can carry a 2-3 kg payload.

Data Processing

LP360 Drone software is bundled with every TrueView sensor. LP360 generates a colorized 3D LIDAR point cloud in LAS format, provides a vast array of product generation tools, and geotags collected images.

Data Management

LP360 Cloud provides a range of services from sensor calibration management to product data hosting and visualization tools.

info@geocue.com

www.geocue.com/trueview

GEOCUE

Carlson Software

APPLICATIONS

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

COMPANY PROFILE

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

We have a large user base, and an exceptional rate of customer retention over our 37-year history, and we are the only company with free tech support since the day of our founding.

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

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Maysville, KY 41056
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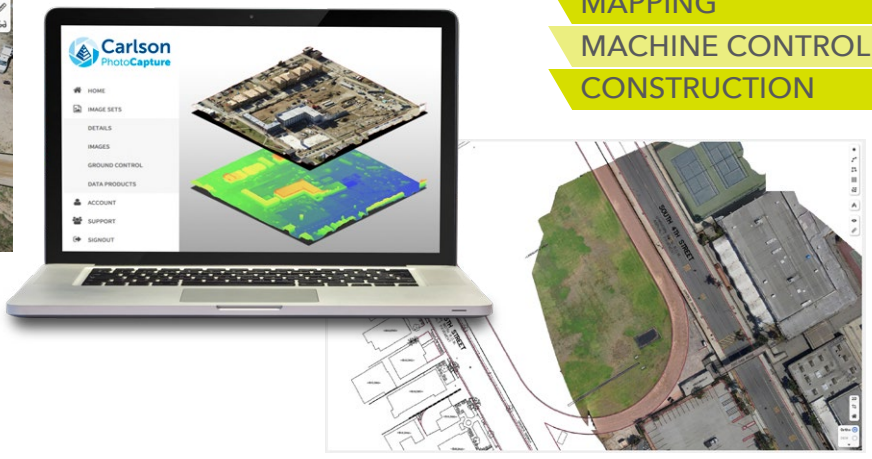
info@carlsonsw.com

carlsonsw.com



Integrated Photogrammetry Solutions

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

Pre-flight, Carlson's CAD office software provides flight planning. Post-flight, Carlson PhotoCapture provides powerful, versatile, scalable photogrammetry processing. It is available in two versions:

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

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

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

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

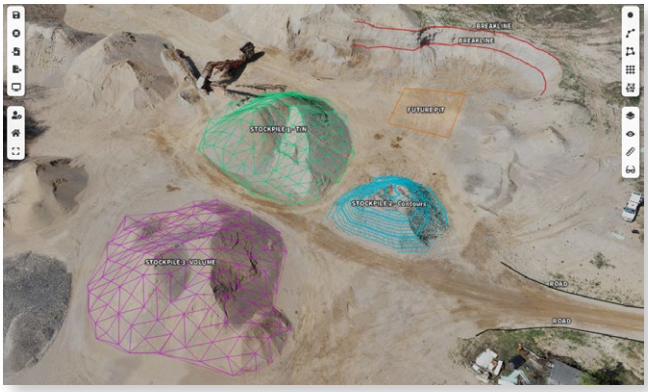
Carlson Software for Photogrammetry

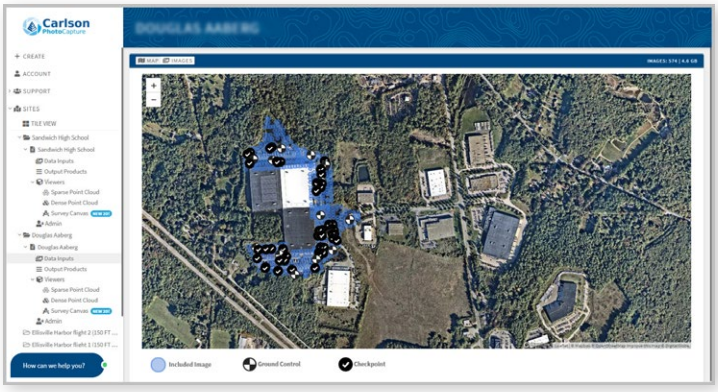
Bridging the Gap Between UAVs and CAD

Carlson PhotoCapture

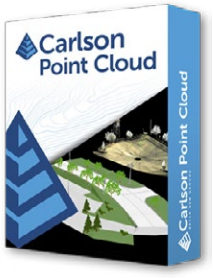
- Choose a perpetual license or cloud-based pay-as-you-go model
- Accuracy through control points and full RTK UAV support
- Output point clouds, volumes, surfaces, elevations, and more
- 30-day free trial

Powerful, versatile, scalable photogrammetry processing. **Online or standalone.**

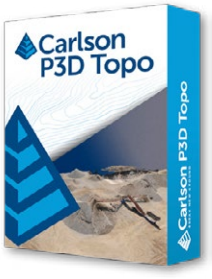




- Sparse or Dense point clouds
- Orthoimages
- Digital Elevation Models
- Project Quality Reports
- Survey Canvas – Virtual Drafting
- Calculate distances, areas, and volumes
- Create points, linework, grids, TINs, and contour lines
- Export in a wide variety of file formats



- Powerful tools such as bare earth and feature extraction
- Point clouds to finished plats
- Point clouds to profiles & sections
- Polylines to CAD



- Powerful point cloud editing in a 3D environment
- Pit/pile volumes
- Surfaces to CAD

Learn more at carlsonsw.com/photogrammetry
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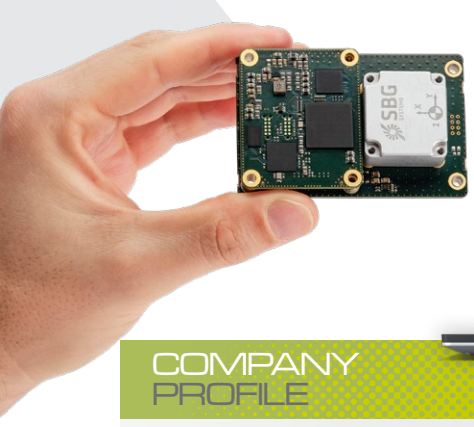
Carlson
BREAK NEW GROUND

SBG SYSTEMS



APPLICATIONS

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

COMPANY PROFILE

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

SBG SYSTEMS

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

sbg-systems.com

SBG Systems Unveils Quanta Plus

The Next-Gen OEM GNSS-Aided INS

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

New Quanta Plus: Optimized SWaP and Stellar Performance in Harsh Environments

Quanta Plus is engineered to deliver accurate and reliable navigation data even in the most demanding environments. It combines a high-performance miniature tactical IMU with a GNSS receiver that is resilient to harsh covering conditions, providing RTK fixes even in challenging situations (0.015° roll/pitch, 0.04° heading, 1cm positioning in RTK).

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

The system boasts a wide range of features to make it easy to use and customize for various applications and features a built-in datalogger, ethernet interface for seamless integration, and a user-friendly web configuration UI for simple setup and control.

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

Enhance Performance with Qinertia Post-processing Software

Qinertia improves the performance of data acquired during a mission using reliable RTK corrections from a wide range of CORS networks, or by importing base station data during the process. It also improves accuracy of the position and attitude using forward and backward processing and by integrating a tight coupling between GNSS and IMU data.

Specific Qinertia solutions are available for integrators and OEMs who want to use Qinertia as a library in their application-specific post-processing solutions.

SBG SYSTEMS

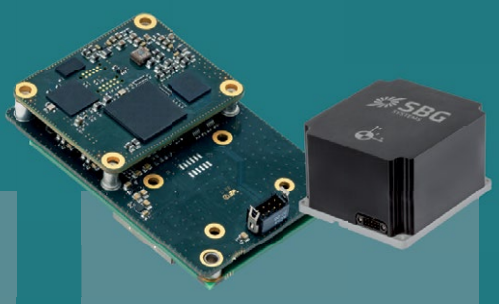
High-Performance INS Solutions for Surveying Applications

NEW QUANTA SERIES

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

Quanta Micro

Quanta Plus



Quanta Extra

l.ead.me/lidarmag2304

From Samsung to Squid Game

3D Laser Scanning for the VFX Industry

The Leica RTC360 3D laser scanner gathers high-quality survey data on set

In the realm of filmmaking and television, 3D laser scanning is increasingly utilized to bring physically impossible worlds and captivating stories to life. Visual effects (VFX) specialists use a technique called Matchmove to generate effects, seamlessly blending live-action footage and realistic computer-generated imagery (CGI). Laser scanning enhances this process, creating evermore immersive worlds and visuals for audiences worldwide.

One pioneering company deploying the power of laser scanning for VFX is South Korea's 75mm Studio Co., Ltd[1]. (75mm). Expert in Matchmove and on-set data captures for the film, television, and gaming industries, 75mm uses 3D laser scanning to conduct digital surveys of sets. These serve as a foundation for applying visual effects to live-action sequences. Using the Leica RTC360[2] 3D laser scanner, 75mm can swiftly and efficiently gather high-quality survey data, even in the most challenging of circumstances – such as on the set of the 2021 Netflix international hit series, *Squid Game*.

However, 75mm's incorporation of 3D laser scanning solutions goes beyond its success with Matchmove. Through lidar technology, 75mm has optimized and expanded its use of point-cloud data, leading to new service offerings for video game development, historical and cultural site documentation, digital twin creation and more.

Converging reality and virtuality: 3D laser scanning takes VFX to new heights

Since deploying 3D laser scanning technology in 2019, 75mm's digital background assets and set surveys have been used for numerous productions. From the Netflix series *Squid Game* and *Kingdom*, to the Korean tvN drama, *Jirisan*, 3D scanning has left an indelible mark on the entertainment landscape. It has also contributed to commercials such as the Samsung Galaxy Z Flip3 music video, where the application of

1 75mm.studio

2 leica-geosystems.com/products/laser-scanners/scanners/leica-rtc360

BY MEGAN HANSEN

75mm interpolating a 3D scan of historical surroundings with live action footage to seamlessly create a convincing battle scene in Netflix series *Kingdom*.

> "With solutions like those used by 75mm, VFX specialists can continually expand the imaginative bounds of the worlds and stories they create to reach new blockbusting heights."

lidar-acquired meshes and textures allowed 75mm to place footage of the K-pop phenomenon BTS into a digital model of a technicolor gymnasium.

"There are various ways to utilize lidar scans in VFX," explains Cholho Shin, CEO of 75mm, "for example, to fill up an empty auditorium or stadium with digital characters or to create a scene with a dangerous car chase in a tunnel. We consider the safety of the actors by filming the scene on set and adding the tunnel scan data after."

From early pre-production through to post-processing, 75mm leverages 3D laser scanning across the entire film production pipeline. During pre-production, the firm captures and delivers survey data of sets to enhance pre-visual directing and scene preparation. On set, it provides survey data to production and set teams, along with computer graphics supervision.

"We use survey data with high-resolution imagery to add background assets to virtual sets," describes Shin. "Additionally, scan data from set locations serves as a great help for live filming."

Through the use of Matchmove in post-production, 75mm delivers a base layout for computer graphics. "We process Matchmove work by utilizing high quality on-set data of the scene and attaching it to the 3D tracked scene," explains Shin.

75mm employs captured survey data from sets to precisely match the geometry of live-action frames and digital environments. This enables VFX specialists to merge live-action footage filmed with 3D cameras into virtual environments to

build computer-generated imagery into scenes, while ensuring action continuity and deepening realism.

Seamless integration and enhanced output with lidar scanning solutions

At the heart of 75mm's Matchmove work lies a powerful duo of laser scanner and software, the Leica RTC360 and Leica Cyclone Register 360[3]. The RTC360 is equipped with lidar, a visual inertial system (VIS) and high-dynamic range (HDR) imaging, so 75mm can scan two million points per second and capture 360-degree HDR images to generate optimal point-cloud results, ready for registration. This allows it to successfully align and georeference point clouds, speeding up post-processing for a much more efficient field-to-finish workflow.

"We normally don't have enough time on real sets for acquisitions, and we have to consider the condition of the filming location," explains Shin. "VIS processing creates 3D point clouds generated from HDR images and this feature allows the scanning process at filming locations to be done quickly with great precision and simple usability."

75mm's work with 3D scanned set data across production stages enables the creation of a convincing car chase scene through a tunnel.

Lidar in hit series

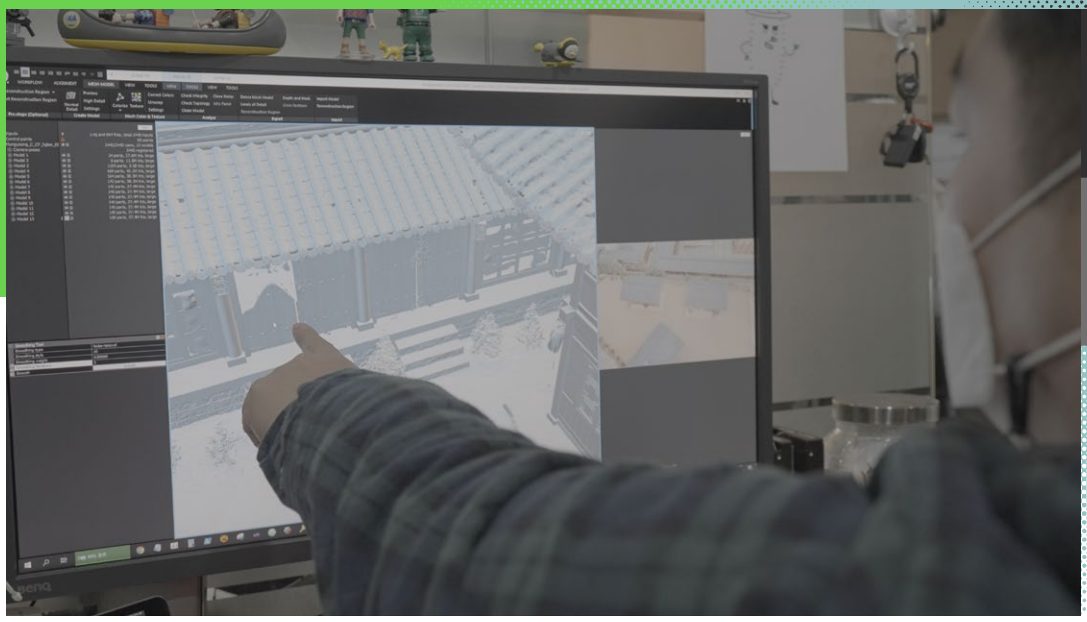
In two recent Netflix series releases, 75mm used set survey scan data to build the foundations for visually stunning scenes.

In the Golden Globe nominated survival drama *Squid Game*, 75mm performed several 3D laser scans of sets for high-precision Matchmove work. One set featured a maze-like cascade of multicolour stairways with complex patterns and textures. The high-accuracy data required to capture the set effectively was possible only with lidar scanning. The number of points captured from the intricate set was massive, and 75mm optimized the vast mesh so the film team could use the survey data easily.

For a scene of life-or-death tug-of-war, they also helped capture set data by scanning a large set with raised platforms. After the actors filmed the scene against a blue screen background with each "team" standing on opposing platforms, 75mm applied its expert Matchmove work and visual effects to complete the perception that the game's losers fell from great heights to their demise.

75mm also scanned sets for Netflix's *Kingdom*, a period horror thriller set in 16th century Korea. They captured locations in the Mungyeong Saejae Provincial Park in central South Korea, a scenic

3 leica-geosystems.com/products/laser-scanners/software/leica-cyclone/leica-cyclone-register-360



A historical building in South Korea reconstructed from a 3D scan for use in the Netflix series *Kingdom*.

mountain pass area with well-preserved historical buildings and an open set for filming. Later, live-action footage was merged with the set survey data to create a seamlessly integrated battle scene.

Laser scanning for the future of filming

3D laser scanning at historical sites like this and other set locations has not only provided 75mm with survey data for its Matchmove work but also helped it to form plans and focus research for where reality-capture technology will take its business in the future.

"Currently, many VFX companies in Korea are planning additional business content through collaboration with our technology and solutions. We are also making efforts to distribute our data to the Korean Federation of Film Archives and the Korean Film Council," says Shin.

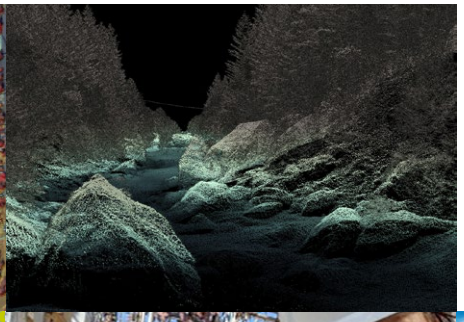
75mm's plans for 3D laser scanning extend far beyond the VFX industry itself. "We are researching how we can use the data in different ways," says Shin. "For example, lidar data can also be used to document historical locations and cultural heritage sites for digital exhibitions, and to create digital assets, like digital twins, for future industries and the metaverse. We are also focusing on optimising the data size and texture while maintaining quality for game engines and augmented reality applications."

A 3D digital replication of an empty sports stadium used to create a version full of spectators.

Lidar promises to be an integral part not only of the future of VFX, but across a vast array of industries for decades to come. With solutions like those used by 75mm, VFX specialists can continually expand the imaginative bounds of the worlds and stories they create to reach new blockbusting heights.

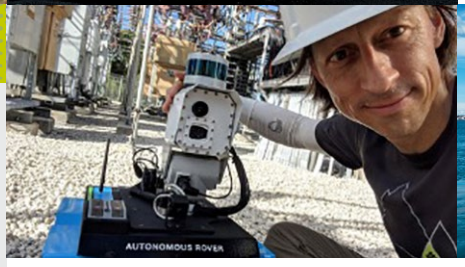
Megan Hansen is a copy writer and SEO specialist at Leica Geosystems, part of Hexagon. Megan writes about the innovation of 3D scanning solutions, sensors and software and the stories of their application across the world.

NV5 Geospatial



APPLICATIONS

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



COMPANY PROFILE

NV5 Geospatial is 1,300+ geospatial professionals across 12+ domestic and international offices delivering end-to-end solutions and insights to organizations who need geospatial information to mitigate risk, plan for growth, better manage resources, and advance scientific understanding.

- We own and operate a wide array of platforms and sensors to collect data globally.
- We apply deep learning, computer vision, and intensive workflow automation to produce deliverables that meet client requirements.
- We build and deploy enterprise GIS environments and use DevSecOps best practices to build, deploy, and support applications.
- We integrate real-time information and perform analytics to assist our customers in making decisions.
- We provide staff augmentation by placing our staff into a customer footprint to meet mission requirements.
- We build, deploy, and support software products that help clients worldwide manage and analyze geospatial data to meet their needs.
- We work with customers across the globe and have completed projects on all 7 continents and in over 182 countries.

NV5 GEOSPATIAL

nv5g-sales@nv5.com
1-800-558-6707
NV5geospatial.com

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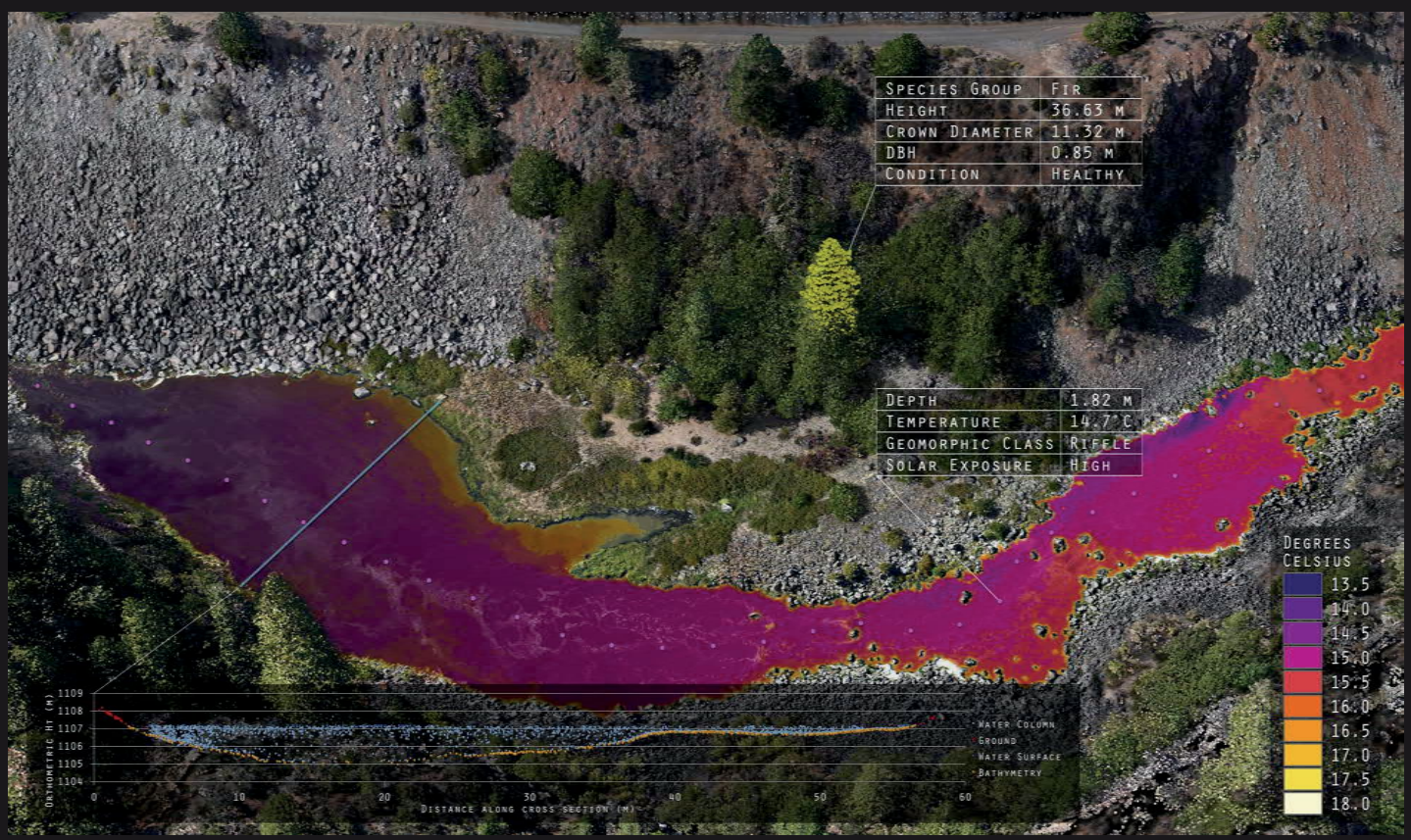

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APPLICATIONS

- SURVEY
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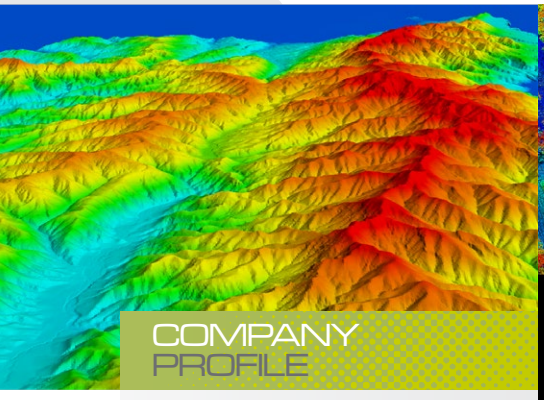

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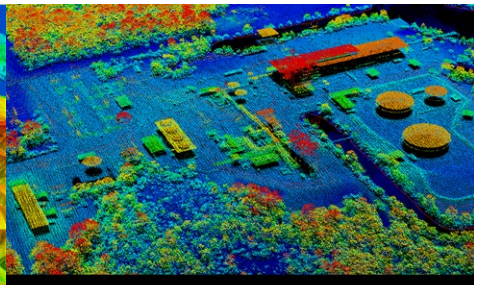

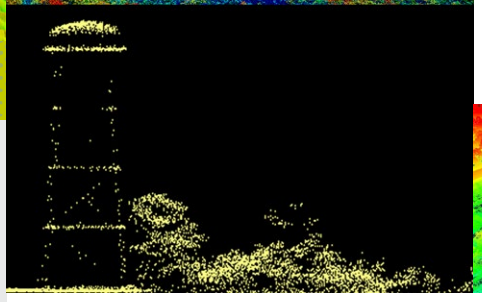

APPLICATIONS

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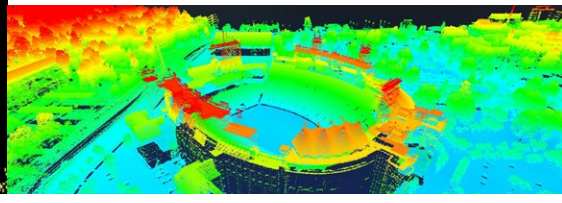
- TOPOGRAPHIC LIDAR
- TOPOBATHYMETRIC LIDAR
- GIS
- APPLICATION DEVELOPMENT
- MODELING
- ASSET MANAGEMENT
- ANALYTICS



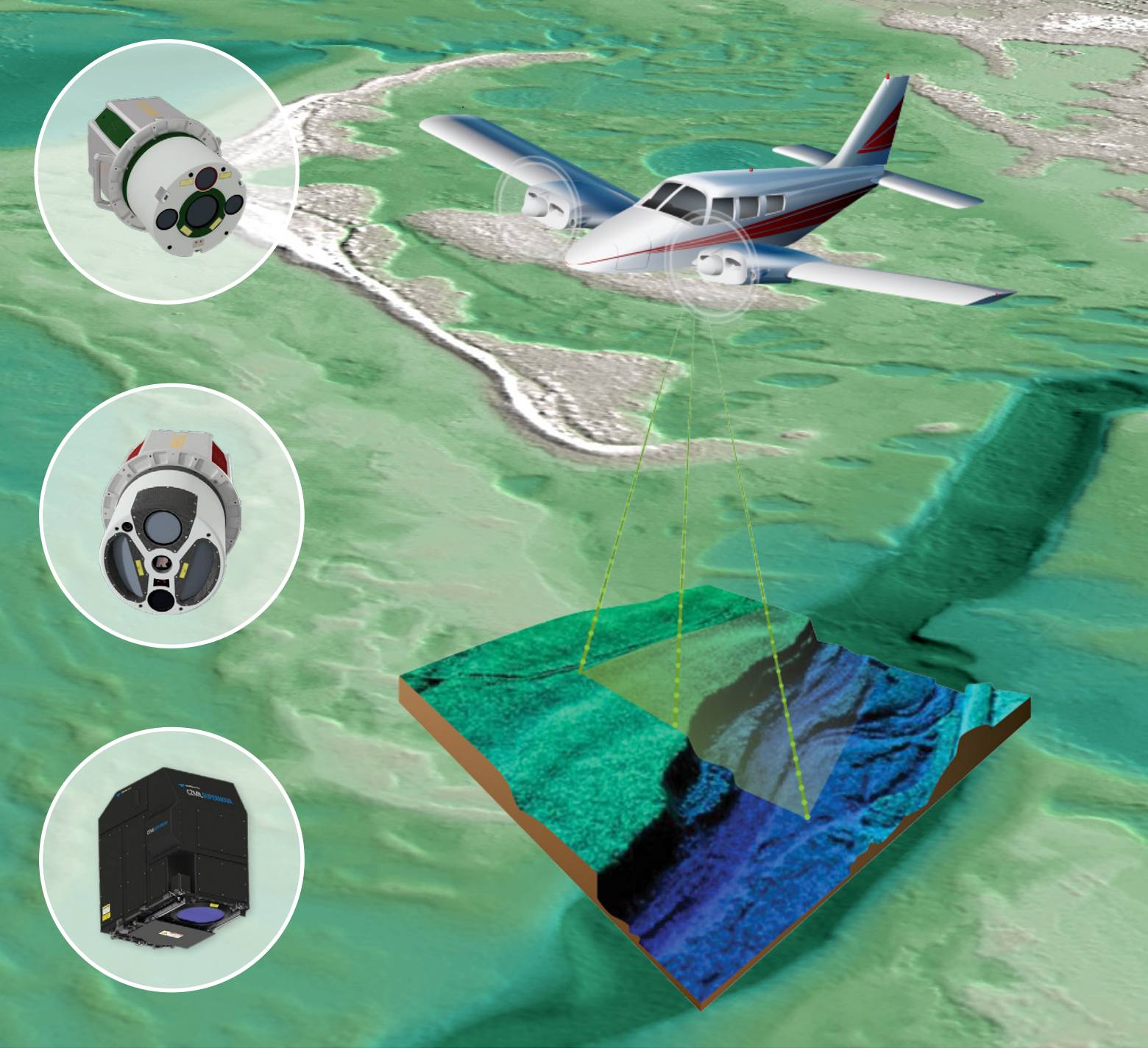
Dewberry's Geospatial and Technology Services

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

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

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

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



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In Australia's Fastest-Growing City, a Digital Twin Guides Rail Expansion

Brisbane team takes advice from London counterparts

BY TERRY **BILLS** AND IAN **KOEPPEL**

The team tasked with designing the first underground railway under the heart of Australia's fastest-growing city knew it would be a delicate task, fraught with infrastructural peril. Tunneling several stories under Brisbane's teeming metropolis, constructing expansive subterranean stations—what could go wrong?

With the scheduled completion less than two years away, it's clear that they made strong choices. But at the outset, nobody knew that the effort would involve an ingenious application of a geographic information system (GIS), creating a detailed and up-to-date 3D model of the project and the Queensland capital city above it, and an immersive digital twin that brings the project to life.

A rapidly growing Queensland

The Queensland government conceived the Cross River Rail project to alleviate population pressures. By 2036, the South East Queensland metro area is projected to add another 1.5 million residents (a number that by itself would make it Australia's fifth-largest city), pushing the region's total population to nearly 5 million.

Most of these new arrivals will live outside Brisbane, but within commuting distance. Many of the new jobs, however, will be in the Brisbane CBD (central business district), on the north bank of the Brisbane River.

Current rail infrastructure is insufficient to handle the necessary increase in CBD-bound train traffic. Cross River Rail will add 6 kilometers of twin tunnels under the river and four new underground stations.

A bigger, better model

Soon after the project was announced, the Cross River Rail Delivery Authority, the overseeing agency created by the Queensland government, sought advice from colleagues on the other side of the world. The Crossrail project in London, launched in 2009, has similar aims, creating new tunnels and ten new underground stations throughout Central London.

Crossrail involves construction beneath a metro area even denser than Brisbane's, with extremely narrow margins to avoid damaging existing underground infrastructure. "They're like our big brother that we idolize," said Russell Vine, Cross River's chief innovation officer.

By the time Cross River's plans were beginning, Crossrail had been under construction for almost seven years. The Cross River team contacted their British counterparts and asked what, if anything, they would do differently if they could start over.

"They basically said, 'We would have built a bigger, better 3D digital model sooner,'" Vine said. The big brother then offered three steps for how to build the perfect GIS-driven digital twin:

- Create a common data environment
- Stipulate that all contractors use the same standards in their 3D architectural models, so that they can be combined into a single model for the project
- Make the model immersive

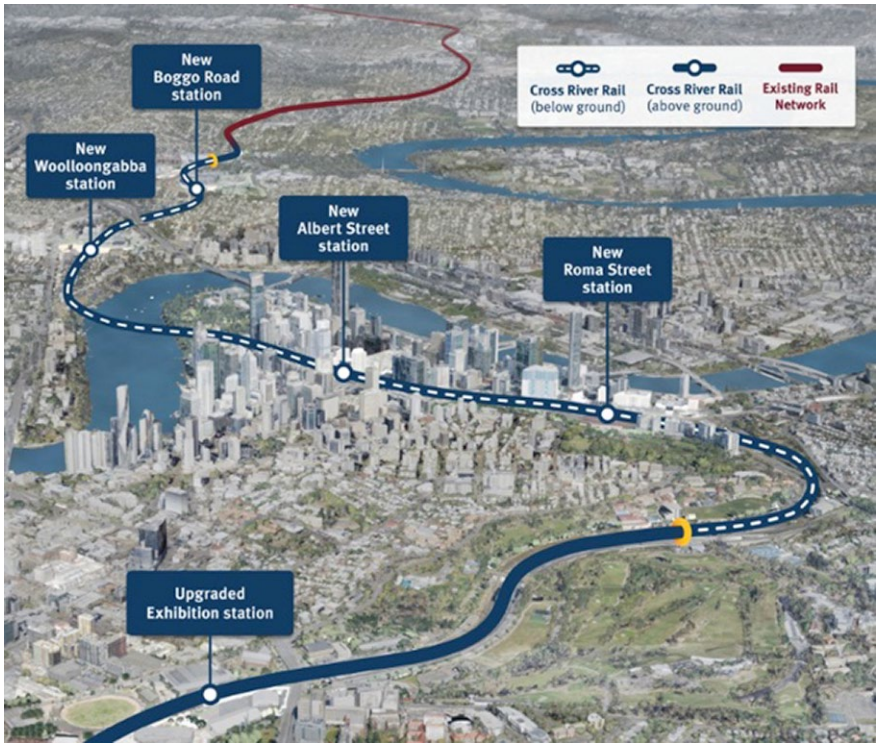
An expansive mission

Crossrail recommended first of all that Cross River create a common data environment for all work. Any project-related dataset, no matter what the format—GIS, building information modeling (BIM), volumetric, photogrammetry, everything—should be in a central repository.

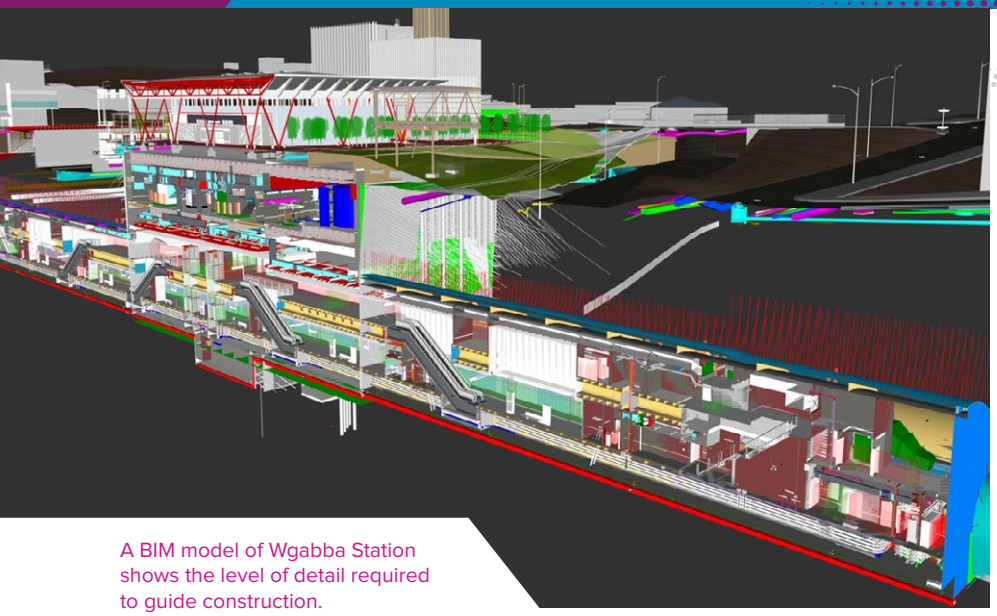
This was useful advice. In recent years, GIS technology has become adept at integrating BIM models and other project-related data formats into a GIS environment. BIM models are 3D architectural models. They describe and depict the actual things being built or dug, while GIS adds contextual awareness.

Rather than just consider the BIM models as inert objects floating in space, people involved in a project can visualize what's around them. In GIS they can see how each structure fits into the infrastructure above ground (such as paths, roads, and light poles), underground (the pipes and lines that connect utility services) and to the natural world (landscaping, groundwater, and even wildlife and biodiversity considerations).

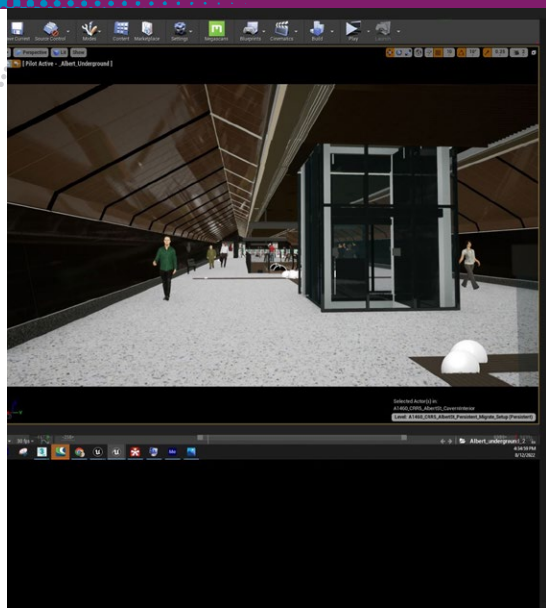
The advice also helped Cross River handle a broad mandate. When Queensland's government created the Cross River Rail Delivery Authority, it required the agency to be responsible



The Cross River Rail project will deliver a new 10.2 km line through Brisbane's inner city, featuring twin 5.9 km tunnels running under the Brisbane River and CBD. Four new underground stations will be built as part of the $5.4b project, in addition to the upgrade of eight existing stations.



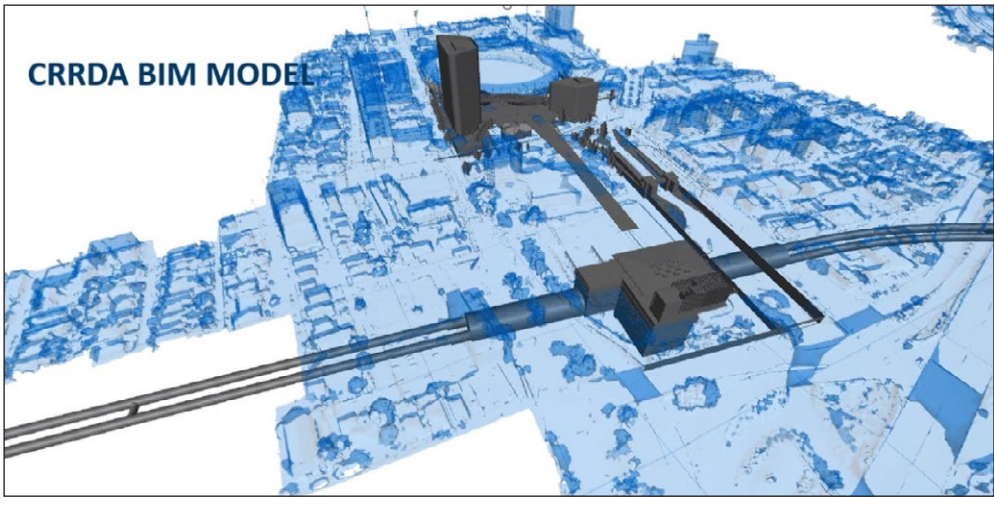
A BIM model of Wgabba Station shows the level of detail required to guide construction.



not just for the railway itself, but also for planning and assessing the project's economic impact.

There was a good reason to include this mandate in the agency's charter. Although Cross River's aim anticipates future developments in the region, its location means Cross River will also *influence* those developments.

"Cross River Rail is going right under the CBD, so the area around the stations is already prime land where the city will grow next," Vine said.



A federated BIM model for Cross River Rail brings together project-wide details for the whole project.

Everything In federation

Crossrail's second piece of advice related to BIM data coming from the project's many contractors and subcontractors. Create a "federated" BIM model, the Brits advised.

That meant combining the disparate BIM information into a single BIM file that depicts everything. For that to happen, Cross River needed to ensure that every contracting entity was using exactly the same data formats, standards, and protocols.

"What the Crossrail team didn't realize until it was too late is that all their contractors were telling Crossrail how they were going to submit their BIM models—it was baked into the contracts," Vine said. "They told us, 'We indulged them, and we shouldn't have.'"

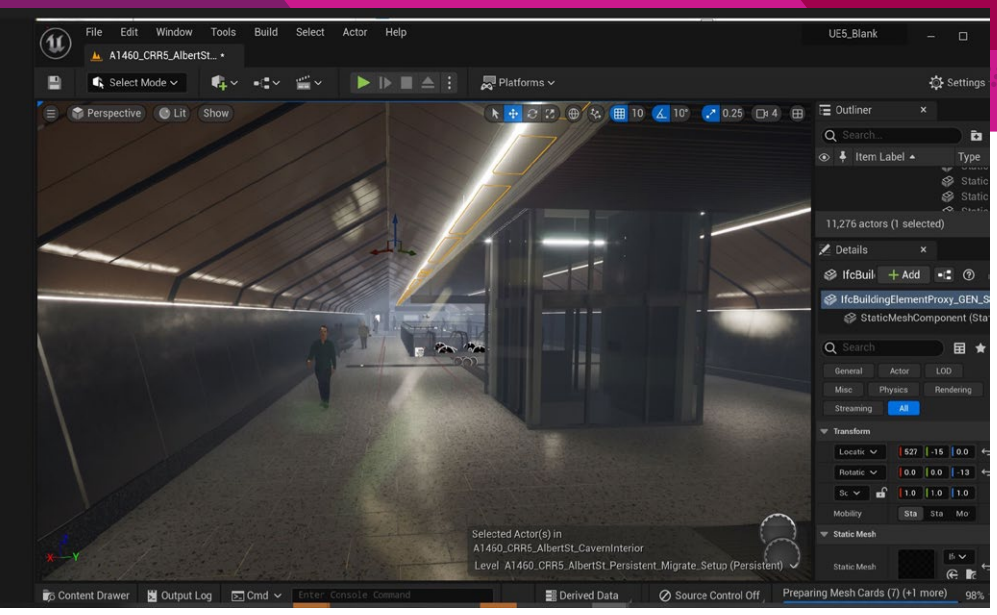
Rail games

Crossrail's third recommendation was, "… the party piece, the one everybody loves," Vine said, because it's about making the model immersive. "They told us they should've put all their data into a game engine and turned it into virtual reality."

The Australian team did just that, using Unreal Engine, a 3D gaming tool, to tie it all together, so anyone sitting anywhere could be transported inside the place they were set to build.

"So we have a federated BIM model of all the stations and all the tunnels, and GIS land mapping in 3D," Vine said. "But then we put it all into Unreal, crank the magic gaming engine handle, and it gives us back a single virtual reality."

The result is 17 kilometers of immersive railway infrastructure that can be explored, like a first-person game, on a screen manipulating a web scene or with a virtual reality (VR) headset. The Cross



Putting BIM models into Unreal Engine allows engineers and other stakeholders to experience each station before they build it.

River team even built a VR theater using a five-way projection system, so that many people can explore the project together.

The VR component transcends mere flash, providing a way for non-technical stakeholders—people not directly involved in the design and construction of Cross River—to view the project as it proceeds. It also gives those who are part of the design team the kind of visual assessments that even the most detailed 3D BIM model cannot provide. As one example, Vine points to the Roma Street station, where teams are experimenting with ways to install a massive art exhibition space on a concourse wall, trying and testing different ideas virtually before they finalize the design and build it.

The digital twin expands to capture all of Brisbane

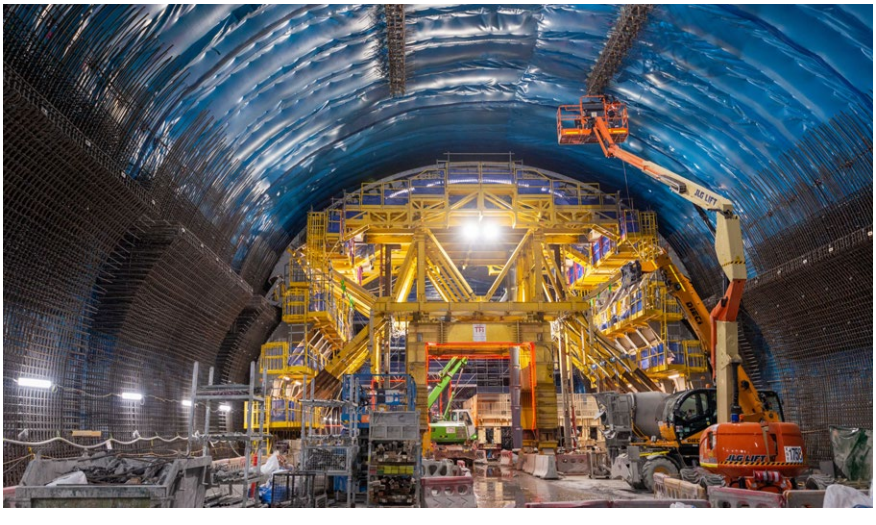
Cross River's commitment to the common data environment (step one of the three-point plan recommended by the Brits) signaled a shift in the usual relationship between GIS and BIM on this kind of large infrastructure project. In the past, GIS would certainly have served as a crucial support player, a context-adding host for the 3D architectural BIM renderings. But given the mandate to document economic development around the train stations, Cross River elevated the importance of GIS. To depict those above-ground areas, Cross River would require skillful 3D maps, including data gathered by lidar sensors to capture engineering-grade measurements.

That, in turn, led to another requirement. The above-ground data would *also* require context.

If the goal was to understand how the stations would affect economic development in the CBD, it didn't make sense to map just the areas around them. A map of the *entire* CBD was necessary. Everything would need to be layered perfectly, so that anything underground (stations, tracks, tunnels, cables, and pipes) lined up in every respect with what was above it.

The result is a 3D land layer that shows lots, utilities, and other pertinent visual information. Cross River's use of 3D even includes material designed in consultation with Brett Leavy, a self-described "cultural heritage digital Jedi" who uses advanced VR technology to recreate pre-colonial Brisbane. Leavy's input, Vine explained, has helped ensure that the project honors and remains respectful of a First Nations perspective.

"We went from 'it's all about building a railway' to 'ah, it's also about rebuilding the city,'" he said. "We ended up making a 3D model of Brisbane, because it was impossible to do one without doing the other."



The Roma Street cavern shows the complexity of the two-tunnel subway line.

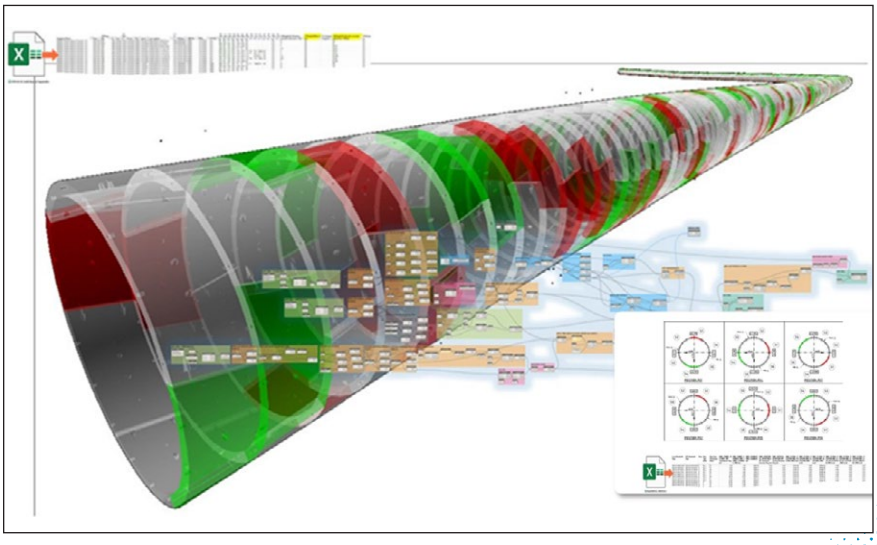
Workers enter the Roma Street cavern to conduct an inspection.

A twin without end

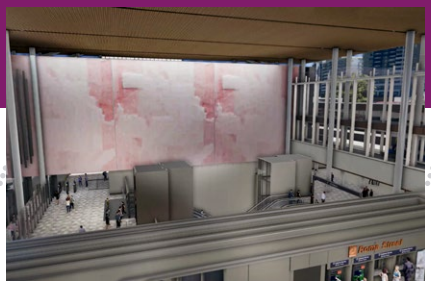
The Cross River digital twin is a continuous work in progress. As designs are finalized and construction proceeds, a staircase or tunnel that existed as a single item in a contractor's initial BIM submission becomes one with thousands of individual components in the federated BIM model.

Beyond just the Cross River project, there's no reason the digital twin can't continue to grow in perpetuity, evolving with Brisbane itself. "We have a running joke about Cross River Rail, that the more you look at it, the bigger it gets," Vine said, noting that after the project began, the city was selected to host the 2032 Summer Olympic Games. "We have an opportunity to take what we've done here as part of building a railway line and stretch it to include everything we're going to need to build for the Olympics."

Vine even foresees the twin being a tool for operating the system in addition to its value in design, construction, and project management. "We realized we've built a digital twin that will help run the railway," he said. "So there's almost a whole second chapter waiting to be written."



For tunnel work, the components and sequencing of parts requires close tracking.



A model of the above-ground element of Roma Street Station shows the colossal art wall that will be a prominent feature of the station.

Terry Bills is the Global Transportation Industry Director at Esri, responsible for all transportation infrastructure segments worldwide. He has more than 25 years of experience in transportation, working on planning, policy development, information technology and GIS. He has been a principal planner for a large regional transportation planning agency, as well as the president of a GIS and transportation consulting firm. He was a doctoral candidate at UCLA, where he also earned two MA degrees.

Ian Koeppel leads international business development for transportation markets in Europe at Esri. He is a cultural geographer, residing in the Loire-Atlantique region of France. Before joining Esri in 1998, Ian was regional sales manager at Etak (now TomTom), managing consultant at Accenture, and director of management information systems at the City of New York Department of Parks & Recreation. An earlier role as research manager at Neighborhood Open Space Coalition included co-authoring the book *Struggle for Space: The Greening of New York City, 1970-1984.*

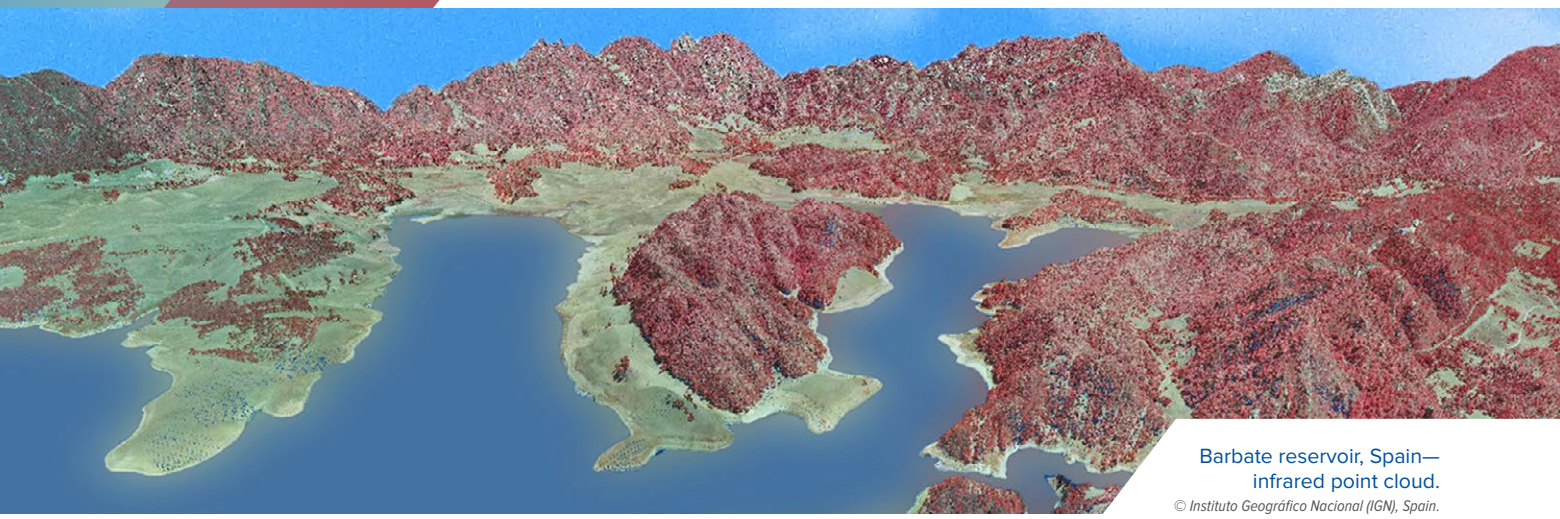
FOR MORE INFO...

Read more about how rail operations use GIS to modernize transportation[1] and how GIS creates digital twins of the natural and built environments[2].

View the "Mega Timelapse" video[3] to see how the project progressed in 2022.

This article originally appeared on Esri Blog[4].

1 esri.com/en-us/industries/rail/overview
2 esri.com/en-us/digital-twin/overview
3 youtube.com/watch?v=eWA_2yIUFW8
4 esri.com/about/newsroom/esri-blog/overview/



Barbate reservoir, Spain—infrared point cloud.

Elevations for the Nations

Understanding Europe's varied approach to lidar mapping

In recent years, the United States has made remarkable progress in the field of lidar mapping through its ambitious 3D Elevation Program (3DEP). This program, managed by the U.S. Geological Survey (USGS), has successfully covered 89.5% of the nation with high-resolution, homogeneous, continuous, and accurate elevation data[1]. This achievement has provided valuable insights and paved the way for crucial decision-making processes. However, a different and complex panorama emerges as we turn our attention across the Atlantic to Europe.

The European Union (EU) still does not regulate mapping activities; instead, this responsibility lies with its Member States. Consequently, lidar coverage in Europe is regulated at the national level, leading to variations and unique characteristics among different countries. In fact, many European countries have not implemented a nationwide lidar coverage plan, instead opting for regional or local initiatives based on their political history and geographic traits. This regional approach has resulted in differing levels of coverage, where some areas have extensive lidar data available, while others are still in the early stages of implementation. Ultimately, access to funding is a pivotal factor, since in many cases the public agencies that carry out the lidar coverage do not have their own funds, but other public organisms commission their services for specific projects (for example, controlling areas at risk of flooding, monitoring the forests).

The European Association of Aerial Surveying Industries (EAASI) has reached out to representatives from national mapping agencies across the continent to gain insights into the status of lidar mapping in their respective countries. The Association comprises over 50 companies, including the most influential players in Europe's aerial mapping sector. Since its creation in 2019 it has actively advocated for a more consistent approach in terms of standards, rules, and certifications.

It is against this backdrop that we embark on a journey to explore lidar coverage in Europe. A range of experiences emerges, highlighting the challenges and achievements of individual nations within a larger European context. Due to time and space limitations, we could include only six countries in this article, but a second installment is in preparation.

1 usgs.gov/3d-elevation-program/what-3dep

BY ADA PERELLO

View from Sevilla City Spain—colored point cloud.

Denmark

Denmark has achieved comprehensive lidar coverage three times since 2007. The country was initially covered with a point density of 0.5 points/m² in 2007, followed by 4-6 points/m² in 2014-15, and currently 8-10 points/m² for the period 2018 to 2023. The decision on point density was influenced by factors such as price and the evolving focus from terrain to vegetation and infrastructure, including building models and power lines.

In terms of innovative applications, Denmark's Styrelsen for Dataforsyning og Infrastruktur is utilizing lidar data for various purposes, including 3D city modeling, power-line mapping, and vegetation determination. Particularly interesting is its work in machine learning, where lidar data is combined with oblique imagery to derive surface types. For this development extra-byte information such as waveform shape deviation and pulse width are used as extra layers to help guide the machine learning processes.

Finland

The National Land Survey of Finland (NLS) is responsible for acquiring laser data for its own needs and those of its state and cooperative partner organizations. This collaborative group, referred to as the KALLIO Cooperation Group, jointly finances the data acquisition.

The country has made significant strides in lidar mapping, achieving nationwide coverage with a point density of 0.5 points/m² from 2008 to 2019. This coverage excludes the outermost islets of the archipelago and the border between Finland and Russia due to operational constraints. Additionally, a laser-scanning program has been developed in collaboration with the KALLIO group since 2020. The program entails scanning Finland on a six-year cycle, with a 12-year program for Northern Lapland. Finland is currently in the fourth year of this program, with detailed information available on NLS's website[2].

In the first lidar coverage, the main purpose was the creation of a two-meter elevation model. Since 2020, the point density has been increased to 5 points/m². This higher density enables various applications, including forest inventory, 3D vectorization of buildings, updating elevation models, and maintaining the topographic database.

Regarding innovative applications of lidar technology, three initiatives are highlighted. The Finnish Forest Centre utilizes laser data for comprehensive forest inventory purposes, aiming to inventory all trees. NLS employs artificial intelligence (AI) and lidar data for building and hydrological network mapping, including ditches. Last, the KALLIO group has a shared processing platform where laser data can be securely processed.

France

France has made significant progress in lidar mapping. The Institut national de l'information géographique et forestière (IGN), the government agency for geographic and forest information in France, will achieve nationwide coverage for the first time in 2023. Previously, lidar acquisitions were limited to areas prone to flood risks, but the new project expands coverage throughout the entire country. France has chosen a point density of 10 points/m² for lidar data collection, allowing it to address multiple public policies such as flood risks, forest management, agriculture, land use planning, and archaeology.

In terms of innovation, France's national mapping agency is incorporating AI algorithms into its lidar data classification process, enhancing accuracy and efficiency. Another relevant innovation

2 tilannekartta.maanmittauslaitos.fi/laserkeilaus

Center of Amsterdam, Netherlands—high-density point cloud.
©het Waterschapshuis, Netherlands.

Sluis, Netherlands—data after classification.
©het Waterschapshuis, Netherlands.

is that it can broadcast lidar data directly from the cloud, eliminating the need for users to download it for visualization.

Netherlands

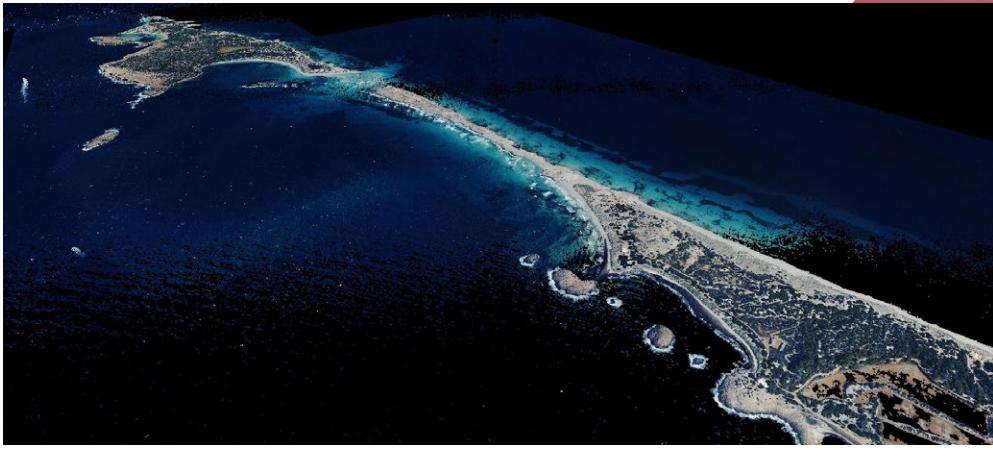
The unique geographic traits of the Netherlands, with a significant portion of the country located below sea level and a flat landscape, have driven the need for gathering geodata on a regular basis for water management and safety. In this regard, het Waterschapshuis, a connecting management organization representing 21 water boards, has been at the forefront of lidar initiatives in the country.

The Netherlands pioneered nation-wide lidar coverage in Europe and has carried out multiple cycles. The initial coverage, from 1997 onwards, focused on capturing elevation data to support water safety initiatives. Subsequent cycles involved capturing a denser point cloud to achieve higher accuracy. Currently, the Netherlands is capturing data at a density of 10-15 points/m², with the aim of updating the national dataset every three years.

In terms of technological innovations, the Netherlands is exploring combined lidar and imagery flights to optimize data collection. By synchronizing lidar and imagery programs, the country aims to capture higher-resolution imagery while maintaining the desired point-cloud density. The integration of oblique images is also being considered to enhance data quality and provide a comprehensive dataset.

As the country has been captured 4-5 times already, the Netherlands is also conducting research on the geometric accuracy of the data acquired. Since 2018, Kadaster, the agency responsible for land registration and mapping, has adopted "dense matching" technologies in the imagery collection, resulting in an abundance of point clouds. Now, the focus lies on evaluating how well these point clouds align, taking into account their varying accuracies.

To ensure data quality and alignment, the Netherlands employs tie lines based on rooftops. By estimating surfaces for each part of the roof, the datasets'



Ses Illetes beach, Formentera, Spain—colored point cloud.
© Instituto Geográfico Nacional (IGN), Spain.

Ajaccio, France—classified point cloud.

congruence can be assessed. This innovative approach allows for a comprehensive evaluation of the point-clouds' accuracy and compatibility, streamlining the data integration process.

Portugal

Portugal's lidar coverage is currently being planned for nationwide implementation by 2024. Execution is scheduled to commence in October 2023, with the aim of achieving full coverage of Portugal mainland for the first time. This ambitious project will provide valuable elevation data that can be utilized by various stakeholders across different sectors.

For lidar data collection, Portugal has chosen a point density of 10 points/m². This decision considers the need for a first-ever comprehensive coverage of the Portuguese mainland, catering to the requirements of multiple users from diverse sectors.

While the acquisition process is currently underway, Portugal's national mapping agency (Direção-Geral do Território) plans to explore the innovative applications of lidar technology once the data acquisition is complete. The agency recognizes the vast potential that lidar offers and intends to leverage it for various applications and sectors.

Spain

Spain's lidar mapping has undergone three distinct phases. The first coverage took place from 2009 to 2015 with a point density of 0.5 points/m². The Instituto Geográfico Nacional (IGN) is the public agency in charge of national mapping, but it is always commissioned by other public institutions that provide the required funding. The driving force behind this initial phase was the General Directorate of Water, and the main focus of the project was flood prevention. The density was determined based on available funds, reflecting a pragmatic approach to what was financially feasible.

The second coverage phase, from 2015 to 2021, encountered challenges due to the use of heterogeneous density. Suppliers were given incentives to improve density within the same price range, resulting in disparate coverage even within the same region. This heterogeneity posed challenges in establishing standardized parameters for data utilization, so a different approach was decided for the next coverage.

Spain's current third coverage phase, from 2022 to 2025, has been facilitated by the Next Generation Funds of the European Union, amounting to 20 million euro. To streamline the process, all tenders were launched simultaneously, three years in advance, allowing successful companies to plan effectively. The density used will be 5 points/m².

In terms of innovation, Spain's national mapping agency has embraced the use of AI algorithms in data classification. A pilot test was conducted, and public consultation was launched to further refine the process. Spain plans to continue researching the possibilities of artificial intelligence.

Conclusion

Taking the above into account, is it feasible to attain at some point consistent lidar coverage across the entire continent? The industry has long advocated for this debate, as the wide variation in tenders and datasets definitions across countries complicates their operations.

Moreover, decision-makers at various levels would undoubtedly gain from having access to comprehensive lidar data from across Europe, given the numerous potential applications of this technology. Harmonizing the tendering process and promoting data availability throughout the continent would be a significant step forward, fostering collaboration and facilitating informed decision-making at a pan-European scale.

The European Union placed a particular focus on high-value datasets such

as geospatial data in its Directive (EU) 2019/1024 of 20 June 2019 on open data and the re-use of public sector information. This Directive also establishes that the Commission is working together with EU countries to define the list of specific high-value datasets that can be made available free of charge and are easily re-usable across the entire EU. However, the homogenization of such datasets seems still to be a distant reality. Creating a pan-European dataset poses challenges, primarily related to funding limitations and differing needs among countries.

Even if all countries consulted for this article recognize the relevance of harmonizing tender structures and classification specifications to facilitate industry collaboration and promote standardization within Europe, they also express caution. The absence of a unified regulatory framework, differing priorities among Member States, and budgetary considerations contribute to the complexity of this endeavor. Nevertheless, discussions surrounding the establishment of a pan-European dataset have gained momentum, emphasizing the importance of collaboration and knowledge exchange between countries.

Despite the obstacles, several European countries have initiated information-sharing meetings to exchange experiences and address common challenges. Since 2022, some countries have met to exchange feedback and experiences, with hopes of moving toward standardized deliverables and improved data accessibility.

It is promising also to see that in addition to their individual efforts, European countries are taking steps to establish a more formal structure for collaboration. The goal is to foster ongoing information exchange and, to facilitate this, there are ongoing discussions to become part of EuroSDR—a not-for-profit organization that connects national mapping and cadastral agencies, research institutes, universities, and companies across Europe.

EuroSDR specializes in applied research related to spatial data provision, management, and delivery. This collaboration platform offers an ideal framework to host the lidar initiative and strengthen communication and ties between European countries.

EAASI will certainly welcome any steps toward the homogenization of datasets. Joining forces, national mapping agencies, pan-European institutions, and the private sector can enhance their collective efforts and ensure continued progress in the field of lidar mapping and geospatial science. Society will be the ultimate beneficiary.

Laguiole, France—classified point cloud.
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***Fries,** continued from page 48*

It is also necessary to scan not only the impact area, but also the lead-up to the impact. Depending on the speed leading up to the accident, several hundred feet should be scanned to capture a contextual lead-up to an accident.

The next step, capturing vehicle and driver data, enables the reconstruction of a true driver's eye-level perspective.

To develop an accurate 3D model of a car, scan the inside and outside of the true vehicle(s) involved (if they survived) or an exemplar model for a foundation of the vehicle's structure. Scanning the inside of a vehicle is especially important when considering the influence of a car's interior on a driver's perspective, whether from the dashboard, hood, doors or A/B pillars. Numerous studies and cases have shown that pedestrians can fit within a vehicle's A or B pillar's visual shadow right up to the point of impact.

Then, to verify where the driver's eye-level perspective would be, reference the perspective driver's height. This number will be used in the next step of modelling and animating the accident.

Finally, with the forementioned data, a 3D artist can animate the environment, vehicle(s), and additional key factors to produce a realistic, evidence-based reconstruction of an accident. By working with evidence or other experts, speeds and additional factors can be fine-tuned to ensure accuracy. This stage is also the best time to model and animate any additional obstructions or unique factors that affected the incident but weren't captured during the scan process.

Once the incident has been animated, placing a perspective camera in the driver's seat will allow an audience to see this accident reconstruction through the eyes of the driver (**Figure 3**). To maintain forensic accuracy, reference the actual driver's height, place a representative 3D model in the seat, then place the perspective camera at the eye-level height of this character.

Figure 2: Lidar scanning of accident scenes accurately and efficiently captures millions of 3D measurement points for forensic-standard reconstructions.

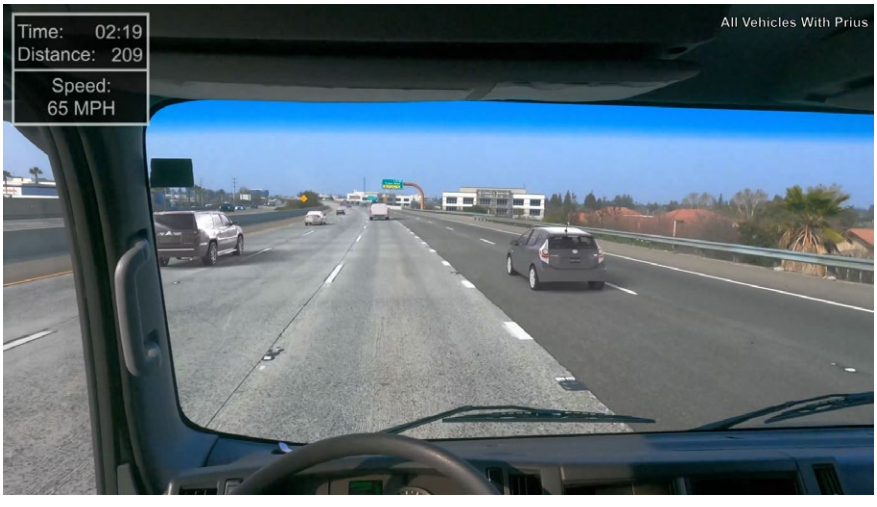

Figure 3: Driver's perspective reconstructions put the audience in the driver's eye.

Finally, rendering the production from this perspective and verifying with a case's experts will yield a 3D accident reconstruction with a truly verified environment and driver perspective. At this stage, an expert can decide whether the 3D animated driver's perspective stands best as a video animation or as an interactive virtual reality exhibit. With technical guidance, virtual reality exhibits can very effectively demonstrate 360-degree perspectives as well as a demonstration of the user's decision-making in an accident reconstruction.

Once completed and rendered, a lidar-based accident perspective reconstruction can be used as several types of key analyses. Below are some very common visual accident analyses:

Line-of-sight analysis

Often, an object's three-dimensional placement can prevent the driver from seeing an impending danger or warning

Figure 4: Animated line-of-sight demonstrative.

in their path of travel. Some examples of internal obstructions can include A/B pillars, vehicle hoods, or blind spots. Common external obstructions can include other vehicles, foot traffic, roadblocks, and tree branches.

Lidar-based reconstruction is an excellent method for verifying whether an obstruction blocked a driver's view. Knowing that the placement and size of each on-screen element and the driver's eye-level perspective have been verified through lidar-scanning ensures that the animation accurately reflects true line-of-sight issues (**Figure 4**). This method is also the safest way to demonstrate these perspectives without physically recreating an accident.

Perception-reaction analysis

The average healthy human's perception-reaction time to potential stimuli is 1 to 1.5 seconds. Because the transmission of information from our brain (perception) to our muscles (reaction) takes this time, one's reaction to an unexpected stimulus may not be in time to avoid disaster. Think of a baseball player swinging at a 100 mph fastball or a deer jumping into a car's path in the woods; just because one sees a potential hazard does not always mean one can reasonably react in time.

This scientific theory is commonly applied to all kinds of forensic cases to audit a reaction to a stimulus. This analysis can be especially useful to analyze the timing and extent of a driver's reaction or lack thereof that led to an accident. By recreating an accident with forensically based space-time demonstrations, a jury or judge can better understand why a driver made a specific decision in the heat of the moment.

"What if?" analysis

When one or two conditions become the primary culprit for an accident case, there is no better tool than 3D reconstruction to answer this case's hypotheticals. For example, if one side wonders, "Could an accident have been avoided if a traffic sign was more visible," it would be easy for a 3D artist to make the traffic sign much more prominent through relocation or by increasing its visibility (**Figure 5**). The same process can be applied to any number of conditions, including, "What if the obstructing tree branch had been removed?", "What if the pedestrian had walked within the crosswalk?", or "What if the driver's headlights worked properly?"

Ultimately, through "What If?" analysis, an audience can view the accident with said modifications then verify whether it would have prevented the drivers from avoiding the accident themselves.

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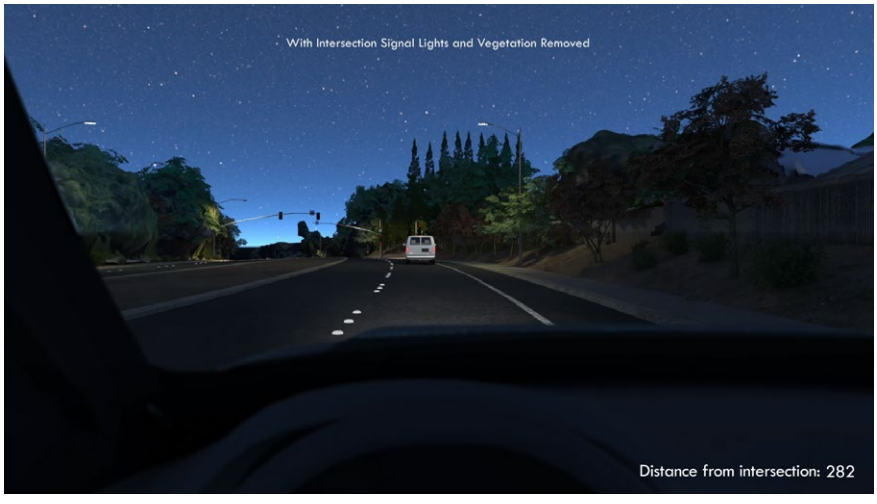

Figure 5: "What if?" analyses are effective demonstratives to showing an alternate context.

Creating Forensic Accident Perspectives with Lidar-Based Modelling

When a serious car accident results in significant damages to one or more parties, an insurance or legal case is opened to determine who was "negligent" and therefore responsible for restitution. Cornell Law School defines negligence as "a failure to behave with the level of care that someone of ordinary prudence would have exercised under the same circumstances."[1] Demonstrating that someone *could* and *did* or *didn't* act within a reasonable standard of care for someone else in a complex accident, however, can be a major task, as this requires uncovering the truth of the incident and the person's perception/perspective during the incident.

Forensic experts have employed a myriad of tools to analyze and communicate a driver's perspective throughout these chaotic situations. Some of these tools include 2D diagrams or video reconstructions. Each of these formats, however, face unique demonstrative challenges: diagrams can't provide first-person perspectives and video reconstructions can't truly capture the details of a traumatic accident where it happened.

With the advancement of 3D reconstruction through lidar technology, however, forensic specialists are employing modern visual technology to demonstrate their accident analyses. Particularly useful tools include 3D animation and virtual reality productions (**Figure 1**). Lidar's infusion with forensic recreation now allows experts to accurately blend a driver's perspective, external obstructions and time-space relationships with efficiency and persuasiveness.

Figure 1: Virtual reality exhibits are becoming increasingly popular tools to demonstrate perspective in an accident reconstruction.

Process

The process to capture the data necessary for a forensic line-of-sight and perspective reconstruction involves capturing environmental 3D data, the vehicle and driver's 3D data and then reconstructing the incident in 3D software.

The primary task is understanding and scanning the environmental setting of the accident (**Figure 2**). Scan data provides experts with an accurate, measurable 3D point-cloud blueprint for a 3D reconstruction. It also sets the stage for the influence of specific conditions or factors that may have led to the accident's outcome, which can be implemented in 3D production.

At this stage, it's important to understand the effect any obstruction may have played in the accident. Vehicles, foot traffic, or other factors may impede the driver's line-of-sight of the road, so it is critical to capture enough data to logically demonstrate potential obstructions in the 3D reconstruction. Pertinent obstructions are often discovered in driver testimony, police reports or from accident reconstruction analyses.

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