LIDAR MAGAZINE

VOLUME 16 ISSUE 2
SPRING 2026

A TOUR OF EUROPE

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Exploring the challenges of discovering, accessing, and harmonizing Europe's fragmented lidar point-cloud datasets via a singular interface

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FROM THE EDITOR

DR. A. STEWART WALKER

A European Flavor

The year began with informative visits to Geo Week in Denver in February and the YellowScan LiDAR Convention 2026 (YLC) in Aix-en-Provence in April. These were very different – the first a major international conference, the second a user meeting with customers from around the globe. The first attracted more than 3000, 25 times as much as the second. These events tend to pass so fast and generate a blur in one's memory — too many products, too many meetings in too short a time. Nevertheless, in Denver I was struck by the tremendous emphasis on AI, which is now prevalent in point classification, feature extraction and far beyond — both suppliers and practitioners use it routinely. In Aix, the impression given by YellowScan's customers was that UAV-lidar is routine, including BVLOS linear collections, but that there is still a sense of adventure. YellowScan itself is transitioning from integrator to manufacturer too, with its Navigator topobathymetric system and other in-house initiatives. Florian Caraveo of YellowScan, who had an article in the last issue of *LIDAR Magazine*, is my co-author of a report soon to be posted on the website about YLC, exploring trends discernible from the content. In each case I returned home inspired by the vibrancy of our lidar industry and its people.

This issue is a little different from usual, in the sense that its content has a European flavor. Daan van der Heide and his Dutch co-authors, from Rijkswaterstaat and Delft University of Technology, describe a portal to enable users to find elevation data in Europe, where the numerous countries and smaller jurisdictions have assembled a wealth of very disparate datasets. This has been brought to our attention in the splendid "Elevations for the Nations" series by Ada Perello of the European Association of Aerial Surveying Industries (EAASI).

Ada is one of our contributors in this issue too. EAASI has come of age and its annual meetings have gained in attendance, stature and value. She describes its seventh summit, in Dubrovnik, Croatia. The resemblance of EAASI to MAPPS is hard to overlook, but Ada is firm that the latter has been "an inspiration rather than a template."

The strength in depth of European geospatial expertise has never been in question – ISPRS started in 1910! The patchwork of countries, their subdivisions and the subdivisions' subdivisions means that there are competent geospatial agencies at all levels, as Marc Riedo's article confirms. He provides a powerful description

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of a windstorm that wreaked havoc in parts of canton Neuchâtel in Switzerland and the data collection that took place immediately thereafter, leading to authoritative support for remedial work and planning for the future. Switzerland is small, certainly, but the area affected was too large for UAV-lidar to be practical, so local company Sixense Helimap was contracted, located near Lausanne in canton Vaud. It deployed a helicopter fitted with its own, custom-built Hexacam sensor. Marc is head of the GIS center in canton Neuchâtel as well as one of his co-authors; the others are from La Chaux-des-Fonds, the city most affected by the windstorm, and Sixense Helimap. Marc is passionate about the use of lidar, especially for forestry applications. He has been talking about these on Swiss TV and radio. We have already received his second article for *LIDAR Magazine*.

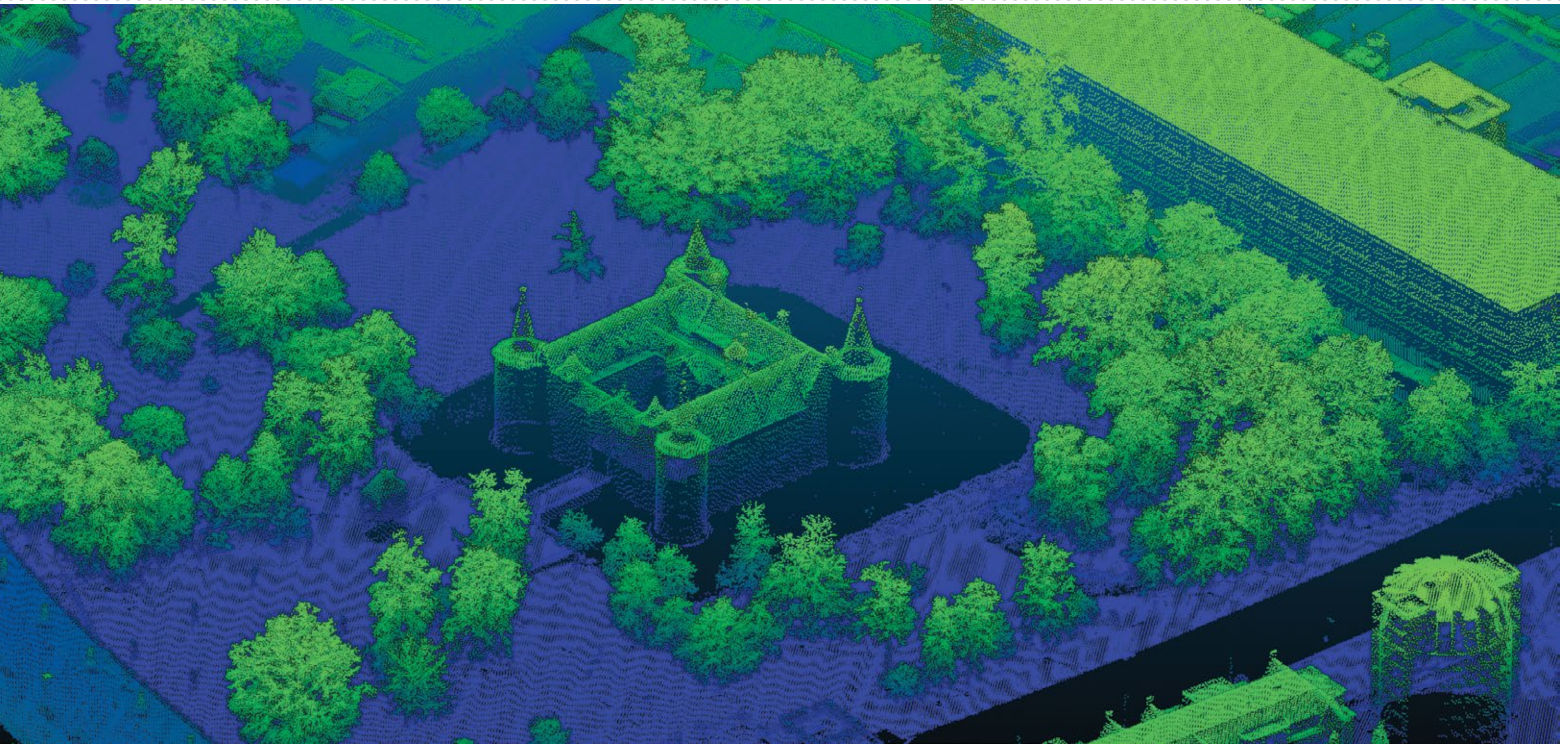
Complementing these three articles from Europe are three from the US – who says we don't have balance? Contributing writer Qassim Abdullah, VP and chief scientist, Woolpert, introduces his idea of smart pixels. Suffice it to say that he advocates every pixel being stuffed not just with color information but with all sorts of data, metadata and linkages. The primary goal is to empower digital twins to fulfill their potential by becoming much more than just stunning, detailed visualizations. We have mentioned this before in the magazine: it's an easy jump from laser scanning to digital twins at their most basic, but it's harder to understand what else is possible, all the way to a digital twin being a dynamic, incredibly powerful, decision-making tool.

Data centers are always in the news. Every day we learn about one, often a Big Tech project, probably bigger than anything before, or using more electricity, or causing arguments about land – anyway, they are ubiquitous, necessary for AI, and critical to our society. Constructing them isn't easy as they have special requirements, including high accuracy and speed. Duane Gleason of Trimble explores how laser scanning is helping meet some of the challenges in this niche of the construction industry. BIM and as-built documentation are essential. Our industry is well placed to meet the demands of these fabulously rich, demanding customers.

The last article is very different and far-reaching. Key to successful bathymetric and topobathymetric lidar projects is mission planning, not just selecting parameters to meet project needs, such as point density and flying height, placing flight lines, considering aviation fuel, air traffic control, battery life and so on, but choosing *when* to fly the mission so that water conditions are optimal for bathymetric lidar. There can be many factors behind this – an easily understood one is that recent rain causes rivers to bring materials and currents to lakes and the ocean such that the water is more turbid. I've had conversations about this with contributing writer Al Karlin of Dewberry, and, at the aforementioned YLC, Michel Assenbaum, president of YellowScan. There are various ways of making the decision when to fly – and obviously the most successful companies are rather good at it – but an extremely promising approach is to use satellite imagery. In an eloquent, well-argued piece, Emily French, a remote sensing specialist at Denver-based TCarta, explains how water clarity monitoring can be accomplished using readily available satellite imagery. Her company's HydroIQ product is already in use by several service companies for their bathymetric work in various parts of the world.

We end with two of our recurring features. Contributing writer John Russo provides his second "USIBD Matters" column with more about the USIBD Level of Accuracy Specification v3.1 and the new *LOA Practitioner's Guide*, recently published to help users apply LOA.

We have a new associate editor of *LIDAR Magazine*, Ron Roth. Many readers will have encountered Ron, truly a lidar guru, when he was product manager for airborne lidar at LH Systems, Leica, Leica Geosystems and Hexagon. Ron and I go back a long way. I first met him in the late 1990s, when he, Doug Flint and others founded a start-up in Massachusetts to produce high-altitude airborne lidar sensors. I was with LH Systems at the time — we made haste to acquire Azimuth and brand the sensor as the Leica ALS40. We have been conscious for some time that *LIDAR Magazine* needs to do more to bring you the news. We post on our website most of the press releases received from companies' communications departments. But lidar is now in both the technical and the popular press every day. Ron's column, "Last Return," is designed to help interpret some of this by taking a big story and looking at what's behind it. In this issue he talks about Ouster's recent announcement of the "world's first native color lidar sensors," its REV08 OS family. Enjoy.



The European Point Cloud Portal

The first step towards a pan-European lidar elevation dataset

A continent rich in data, yet hard to navigate

Europe is rich in lidar point-cloud data, but finding it is surprisingly hard. National, regional, city, and research initiatives alike have produced detailed elevation datasets at varying spatial scales, resulting in a fragmented catalogue of independently maintained point clouds. Studies from Kakoulaki *et al.* (2021) for the Joint Research Centre, Perello (2023, 2024, 2025) in this magazine, and most recently van der Heide *et al.* (2026) have all documented this richness and the challenge of building a harmonised pan-European dataset.

Despite this abundance, the point cloud datasets remain fragmented. Each country, region, city or scientific initiative maintains its own data portal, with varying access policies, formats, and metadata standards. Together, the review studies by Kakoulaki, Perello, and van der Heide point to a shared conclusion: a seamless, pan-European lidar-based elevation model remains missing, even though the data is abundantly available.

BY DAAN **VAN DER HEIDE,**
JANTIEN **STOTER,** GINA **STAVROPOULOU**

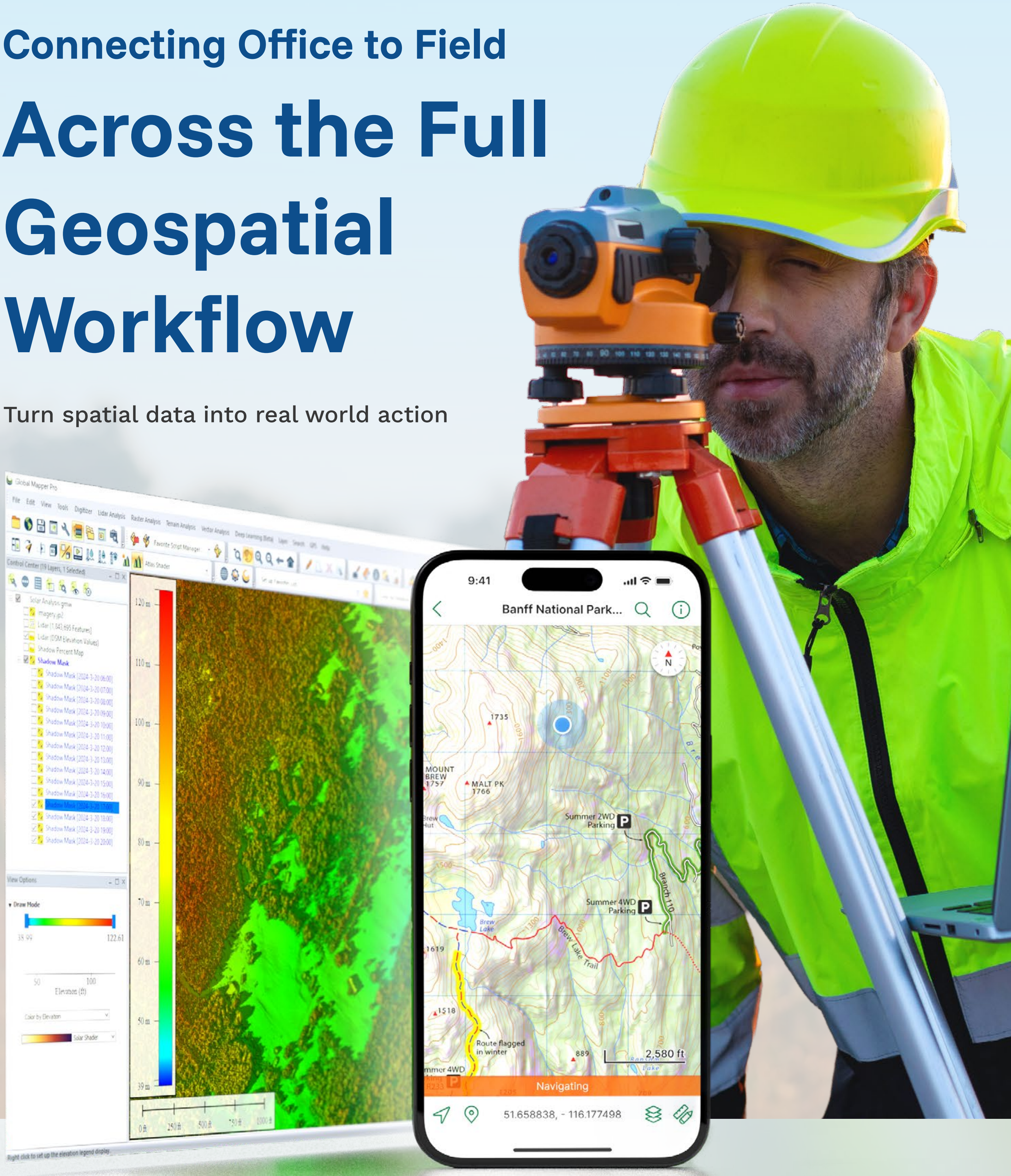
The discoverability challenge in European lidar data

Arguably, the primary barrier to a pan-European lidar dataset is the data's discoverability. European point-cloud datasets are distributed across dozens of independent portals, each with its own interface, language, documentation style, data formats, download mechanisms, and licenses.

Connecting Office to Field

Across the Full Geospatial Workflow

Turn spatial data into real world action



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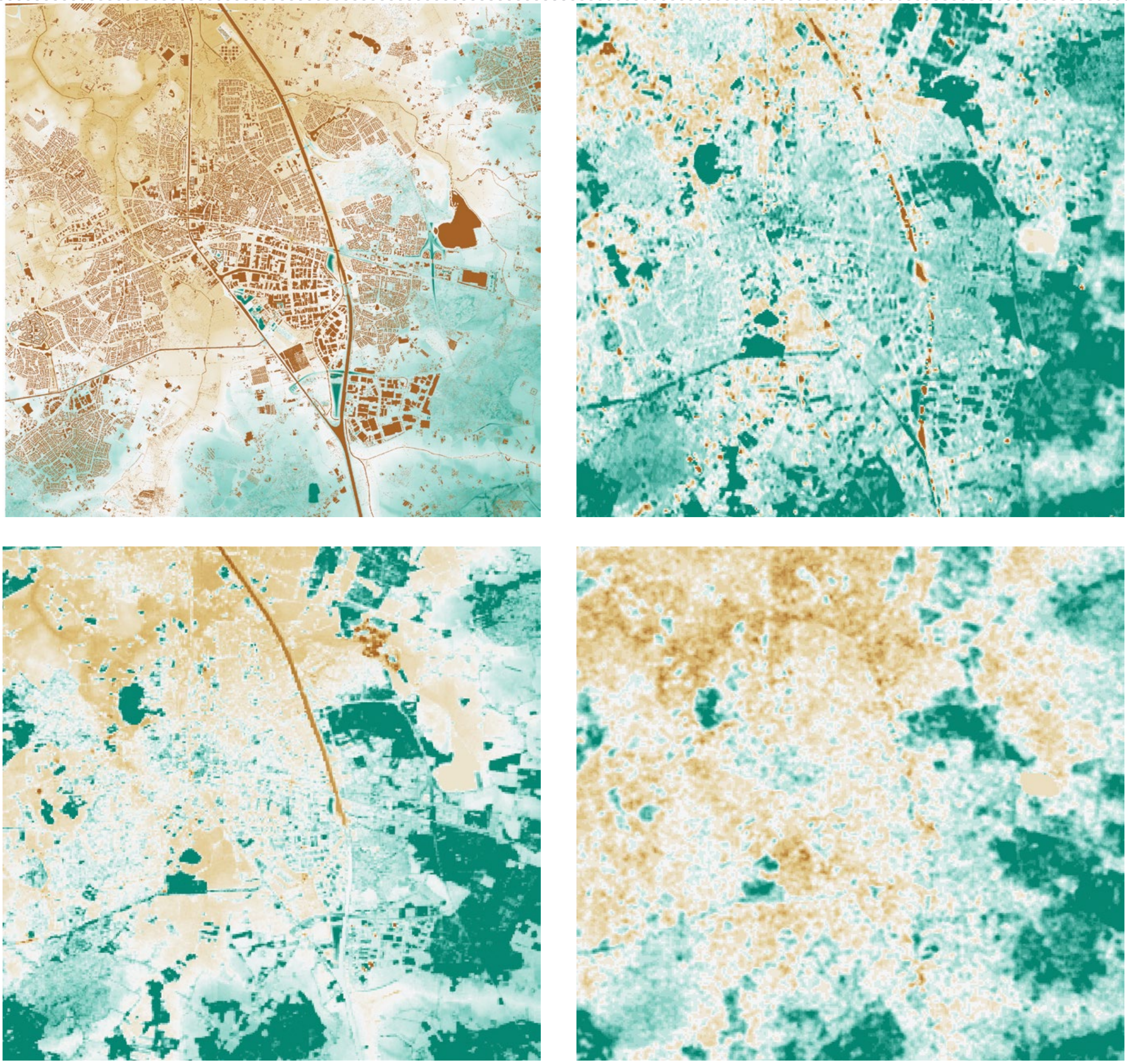
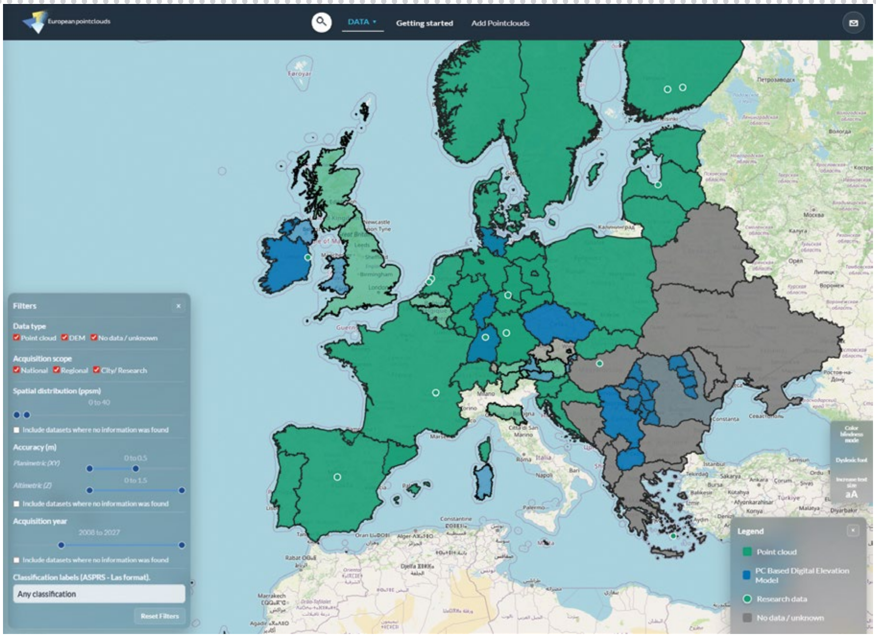


Figure 1: Snapshot of the city of Helmond, Netherlands from various publicly available elevation datasets: Actueel Hoogtebestand Nederland DTM, grid size 5 m (top left); ALOS World 3D, grid size 30 m (top right); EU-DEM, grid size 30 m (lower left); NASA-DEM, grid size 30 m (lower right).

For point-cloud users, this means that discovering relevant datasets is often time-consuming. Even when the point cloud is found, understanding its specifications requires navigating unfamiliar metadata structures or translating different documentation. Even a simple question, such as the spatial distribution of lidar point clouds in Europe, is challenging to answer. Unlike the United States, where platforms such as OpenTopography provide centralized access to a wide range of datasets, Europe lacks a unified interactive entry point.

Alternatives such as the Copernicus EU-DEM, NASA-DEM, and ALOS World 3D are available for cross-border use, but their resolutions cap at 30 m, which is sufficient for continental models but inadequate for the infrastructure and housing challenges Europe faces. **Figure 1** illustrates examples of each available

Figure 2: Homepage of the European Point Cloud Portal.



Filters

Data type
☑ Point cloud ☑ DEM ☑ No data / unknown

Acquisition scope
☑ National ☑ Regional ☑ City/ Research

Spatial distribution (ppsm)
0 to 40
☐ Include datasets where no information was found

Accuracy (m)
Planimetric (XY) 0 to 0.5
Altimetric (Z) 0 to 1.5
☐ Include datasets where no information was found

Acquisition year
2008 to 2027
☐ Include datasets where no information was found

Classification labels (ASPRS - Las format).
Any classification

Reset Filters

Figure 3: Example of different datasets and filters available in the portal.

open elevation dataset, comparing the national lidar-based dataset in the Netherlands (top left) with ALOS World 3D (top right), EU-DEM (lower left), and NASA-DEM (lower right).

Introducing the European Point Cloud Portal

To address the challenge of discoverability in pan-European lidar datasets, we created the **European Point Cloud Portal (Figure 2)**. This was developed as an open, interactive gateway for discovering lidar datasets across Europe and is a continuation of the EuroSDR[1] work (van der Heide *et al.*, 2026). It is hosted by the 3D Geoinformation research group of Delft University of Technology to ensure the platform's long-term sustainability.

In contrast to platforms such as OpenTopography, the European Point Cloud Portal does not aim to host the datasets centrally; rather, it takes a federated approach, where data remains at its local source while the portal guides users interactively to the relevant data sites. This federated approach aligns with European data governance principles, such as those promoted by INSPIRE (Infrastructure for Spatial Information in Europe) and the GreenData4All initiative of the European Union, both focused on enabling interoperability between national datasets while keeping data at the source.

The European Point Cloud Portal catalogs datasets from a wide range of open providers, including national mapping agencies (e.g., annual ALS campaigns), regional authorities (e.g., provinces, states, or Bundesländer), municipalities (e.g., city-scale acquisitions), and scientific initiatives. At present 134 point clouds or elevation models based on point clouds are discoverable via the portal. All have different scopes, specifications, and acquisition platforms, providing a diverse range of datasets that can be interactively filtered in the portal to quickly access the desired data (**Figure 3**).

Understanding the European Point Cloud dialects

In the context of a pan-European dataset, variations between point clouds affect how datasets can be used, compared, and combined. These were formalized in the EuroSDR study by treating them as European dialects. Based on a questionnaire administered to members of the EuroSDR and municipalities in the Netherlands, the so-called dialects were categorized into four primary groups (**Figure 4**): (1) spatial distribution, (2) accuracy, (3) classification, and (4) coordinate reference system.

The spatial distribution is often described in 2D point density, e.g., points per square meter (ppsm). Only a few datasets address the three-dimensional aspect of spatial distribution in point clouds, for instance connecting the distance between the points to the point density. The trend in Europe is that national datasets range from 5.5 to 14 ppsm, with a distinct difference between urban and non-urban areas. Focused city or research datasets have far denser spatial distributions, often due to the acquisition method.

The second category, the accuracy levels, is often divided into absolute

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[1] https://www.eurosdr.net/

Figure 4: Overview of all the metadata, including the acquisition, coverage, quality and the link to the site of the Spanish point cloud dataset PNOA.

(e.g., how well the point cloud is placed with respect to the real environment) and relative (e.g., how well the points are distributed within a single acquisition). The values at both levels depend heavily on acquisition methods, sensor quality, and processing workflows.

The third category is the presence of classification labels in point cloud datasets, where the availability and manner of classification guide the selection of the dataset. However, classification schemes are not (yet) standardized across Europe. So, from the perspective of a pan-European dataset, harmonizing cross-border datasets with classification but varying definitions can impose a challenge. Hence, the portal includes dataset classification, as defined by the Open Geospatial Consortium LAS Specification 1.4, rather than the USGS LAS definition table. Thus the user can quickly see the definitions and, for example, what a dataset classifies as low, medium, or high vegetation.

Perhaps the most visible and technically challenging category is the coordinate reference system. European datasets use a wide variety of planimetric and altimetric reference systems. In total, 51 different planimetric and altimetric coordinate systems are used, with 11 countries using the UTM reference system and 16 countries using horizontal systems closely linked to ETRS89. Notably, this point-cloud dialect becomes apparent as no two datasets share the same elevation reference system.

Paving the road to a Pan-European dataset

The European Point Cloud Portal is a step toward an open European dataset comparable with the EU-DEM. By introducing the concept of point-cloud dialects and providing a structured, interactive platform for dataset discovery, it gives anyone working with lidar data across Europe a practical starting point for finding and comparing the right dataset. The portal is growing, and the path toward a seamless, pan-European point cloud dataset is becoming clearer. ▪

Please let us know whether your open point cloud datasets should be included in the European point cloud portal at *<u>europeanpointclouds.tudelft.nl.</u>*

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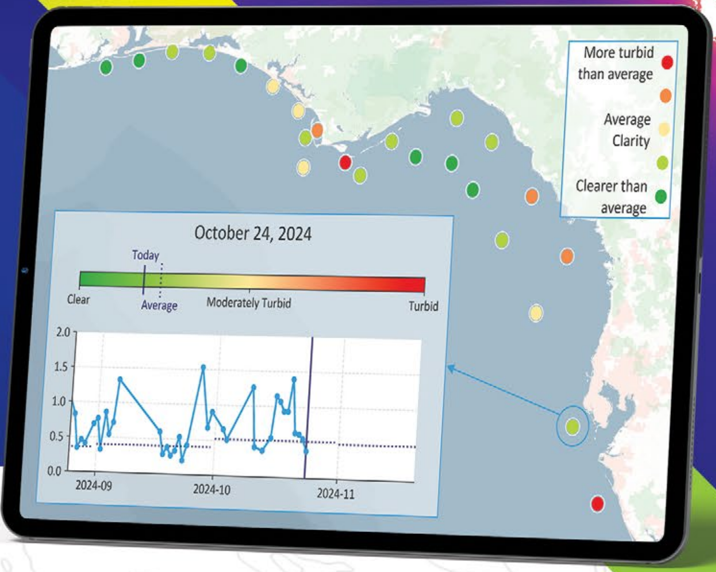
Daan van der Heide is a technical advisor in sensor technology at Rijkswaterstaat in the Netherlands, where his PhD research at the 3D Geoinformation group of Delft University of Technology focuses on harmonizing point cloud datasets into a cross-border federated dataset. The European Point Cloud Portal is the first outcome of that research.

Jantien Stoter is Professor 3D Geoinformation, Urban Data Science section, Delft University of Technology. Her research areas are 3D city modeling, geospatial information modeling and GeoBIM. She is also vice-president of EuroSDR.

Gina Stavropoulou is a data and software engineer in the 3D geoinformation group at the Faculty of Architecture, Delft University of Technology (TU Delft), and a developer on the 3DBAG team.


More turbid than average
Average Clarity
Clearer than average
October 24, 2024
Today
Clear
Average
Moderately Turbid
Turbid
2.0
1.5
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0.5
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2024-10
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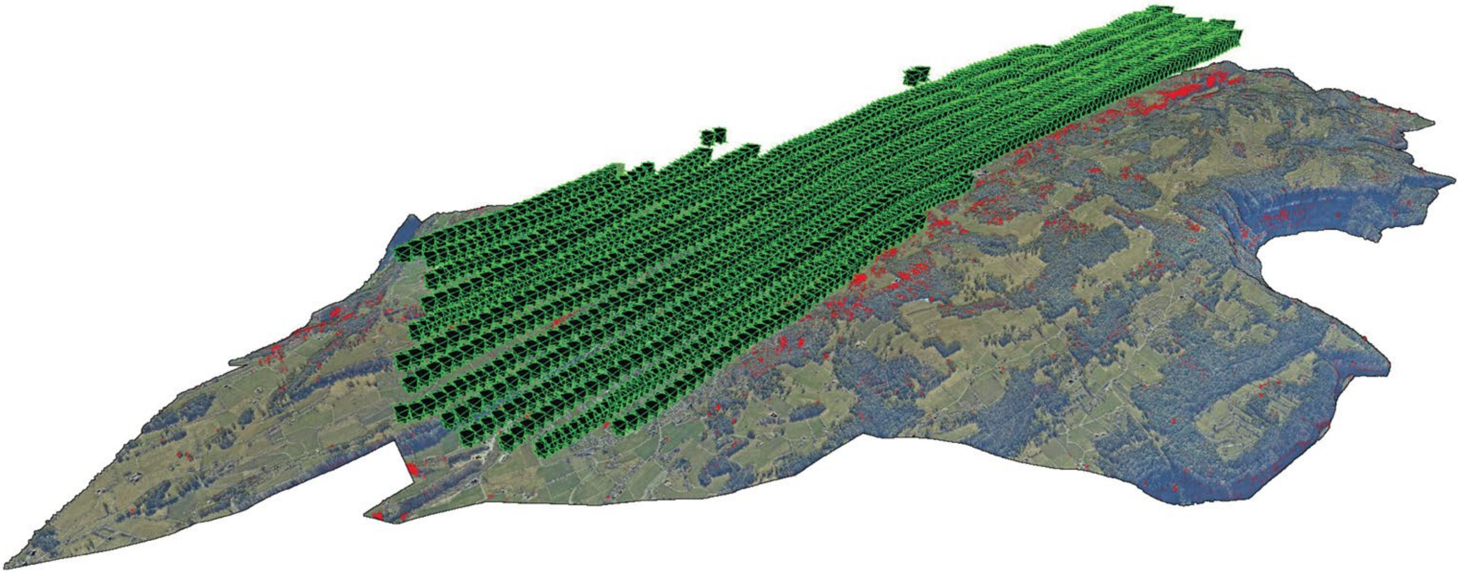

Emergency Mapping for Documenting and Managing Natural Hazards

Example of the storm of July 24, 2023 in La Chaux-de-Fonds, Switzerland

The increasing frequency and intensity of extreme weather events require efficient methods for documenting, analyzing, and managing natural disasters. Using the storm that struck La Chaux-de-Fonds (canton of Neuchâtel, Switzerland) on July 24, 2023 as a case study, this article demonstrates the critical contribution of geomatics to crisis management and post-event analysis.

High-resolution airborne surveys combining orthophotography, oblique imagery, and high-density lidar enabled rapid and comprehensive three-dimensional documentation of the affected area. The resulting datasets supported emergency response operations, insurance assessment, forest damage analysis, and decision-making processes across multiple institutions.

This article presents the acquisition strategy, data processing workflow, and the main geospatial products generated, along with feedback from operational users. The experience highlights the importance of rapid

BY MARC **RIEDO,** MATTHEW **PARKAN,** JULIEN **VALLET,**
HUGUES **FOURNIER,** DAVID **ULRICH,** GILDAS **ALLAZ**

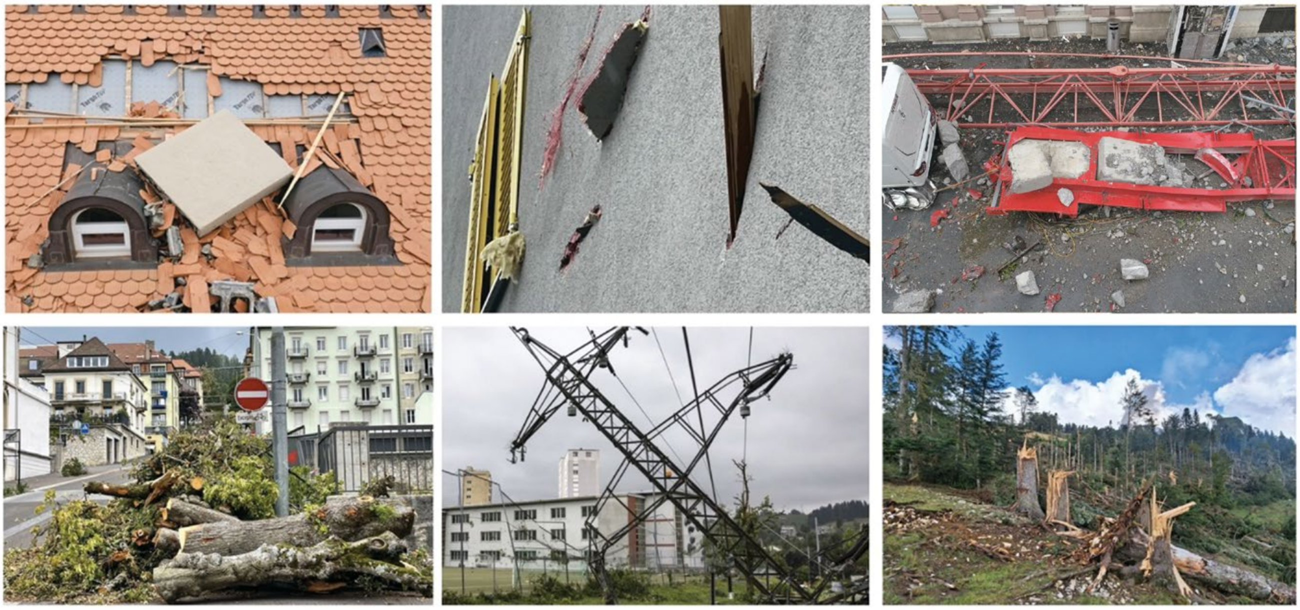

Figure 1: Images of the damage. Sources: Pierre Schneider, municipal engineer (top three images and lower left); La Chaux-de-Fonds Police Department (lower center); Pascal Schneider, SFFN (lower right).

data acquisition, integrated 2D and 3D visualization tools, and AI-assisted lidar processing in emergency contexts. The results demonstrate that timely access to geospatial data significantly improves situational awareness, coordination, and recovery planning following extreme events.

Introduction

Climate change is contributing to the increasing frequency and intensity of extreme weather events worldwide. These events place growing pressure on both natural and built environments, often causing severe damage to infrastructure, forests, and urban areas. While risk prevention and preparedness remain essential, post-event documentation has become equally important for understanding event dynamics, improving mitigation strategies, and supporting effective crisis management.

Post-event mapping plays a central role in this process by enabling rapid and accurate three-dimensional documentation of affected areas. High-resolution geospatial data provides decision-makers with the information required to assess damage, coordinate emergency operations, and support recovery efforts. In addition, such datasets contribute to long-term analysis through numerical modeling, risk assessment, and improved prevention measures.

This article presents the contribution of geomatics to the management of the severe windstorm that struck La Chaux-de-Fonds. The event, characterized by peak wind speeds of up to 217 km/h, was described by the Swiss Federal Office for Meteorology and Climatology (MeteoSwiss) as a hybrid phenomenon combining characteristics of both a tornado and a microburst. Although the event lasted less than ten minutes, its sudden and unpredictable nature prevented the issuance of an advance warning. The consequences were severe, resulting in one fatality, 45 injuries, damage to approximately 3000 buildings, impacts on more than 25,000 trees, and building damage exceeding CHF 120 million (**Figures 1** and **2**).

Faced with the scale of the event and the urgency of the situation, multiple institutions collaborated to rapidly

Figure 2: These images of a wooden area, acquired before (top) and after (bottom) the windstorm, highlight the severity and suddenness of the damage.

acquire and process high-resolution airborne data. This paper describes the acquisition strategy, the geomatics methods employed, and the operational benefits observed through feedback from emergency services, insurance authorities, forestry services, and meteorological experts.

The canton of Neuchâtel's Geomatics Office (Système d'Information du Territoire Neuchâtelois - SITN), the city of La Chaux-de-Fonds's Geomatics Department and the Cantonal Insurance Institution (ECAP) coordinated their efforts to commission Sixense Helimap[1] to carry out high-resolution surveys by helicopter. This enabled them to collect orthophotos with resolutions of 2, 5, and 10 cm, oblique images (Hexacam system: **Figure 3**), and lidar (100 ppsm). One of the major challenges of these acquisition campaigns was the speed with which the data had to be collected and made available. Sixense Helimap carried out an initial flyover on July 27, followed by delivery of the raw images on July 28 and delivery of the orthophotos on July 29. A refined version was delivered with the lidar data on August 3 eight days after the event. The orthophotos were published on the canton geoportal on the day they were received, providing considerable assistance to the emergency services responsible for securing roofs. The combination of orthophotos, oblique images, and very high-density 3D lidar surveys, and their comparison with campaigns prior to the storm, proved extremely valuable and effective. To speed up data processing, artificial intelligence was used to automatically classify standing and fallen tree trunks in the lidar point cloud.

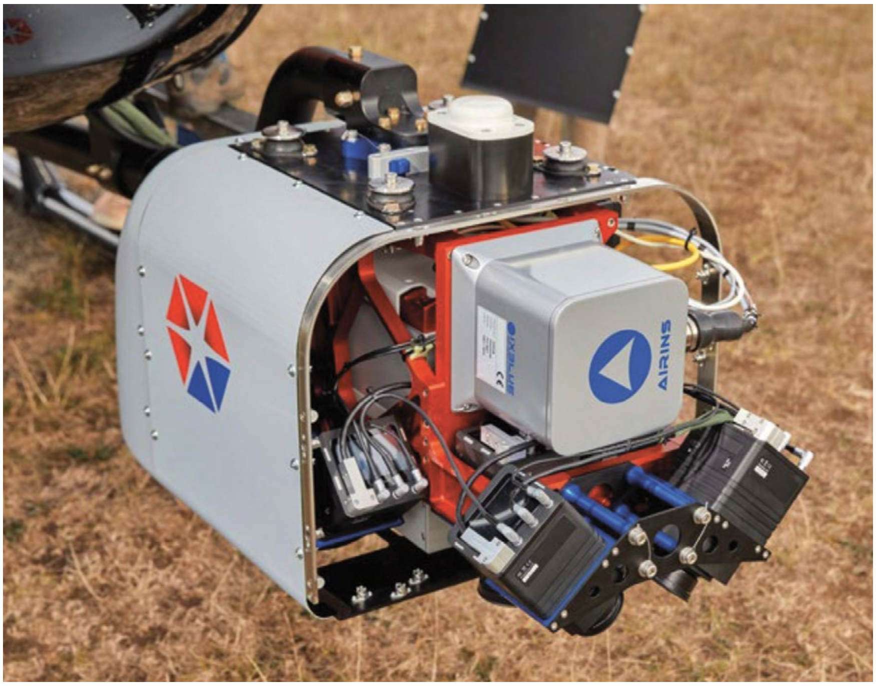

Figure 3: Hexacam sensor for acquiring lidar data and very high-resolution nadir and oblique RGB-NIR images.

Data acquisition and mapping strategy

Given the extent of the affected area, which included the cities of La Chaux-de-Fonds and Le Locle as well as surrounding forest areas, drones were not suitable for providing homogeneous emergency coverage. The urban area alone covered more than 30 km², making crewed helicopter-based acquisition the most practical solution.

A combined lidar and photogrammetry approach enabled rapid acquisition of high-resolution orthophotos over large areas. As Les Eplatures Airport is located within the area of interest, specific authorizations were required to operate within the controlled airspace (CTR). On July 27, less than 72 hours after the storm, an initial flight covering approximately 30 km² of urban areas was carried out between 9:40 a.m. and 11:30 a.m. During this mission, nearly 5000 images with a ground resolution of 2 cm were acquired, together with a lidar point cloud with a nominal density of approximately 60 ppsm.

Following consultation with the various stakeholders, the acquisition area was subsequently extended to the surrounding forests to assess the damage. A second flight was conducted on August 10, 2023, at an altitude of approximately 850 m above ground level, covering an area of 40 km² between 9:30 a.m. and 10:40 a.m. This mission acquired approximately 700 RGB-NIR images with a ground resolution of 9 cm, together with a lidar point cloud (35 ppsm).

A third flight was carried out on November 8, prior to the onset of winter conditions, to monitor the progress of roof repair.

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[1] https://helimap.ch/

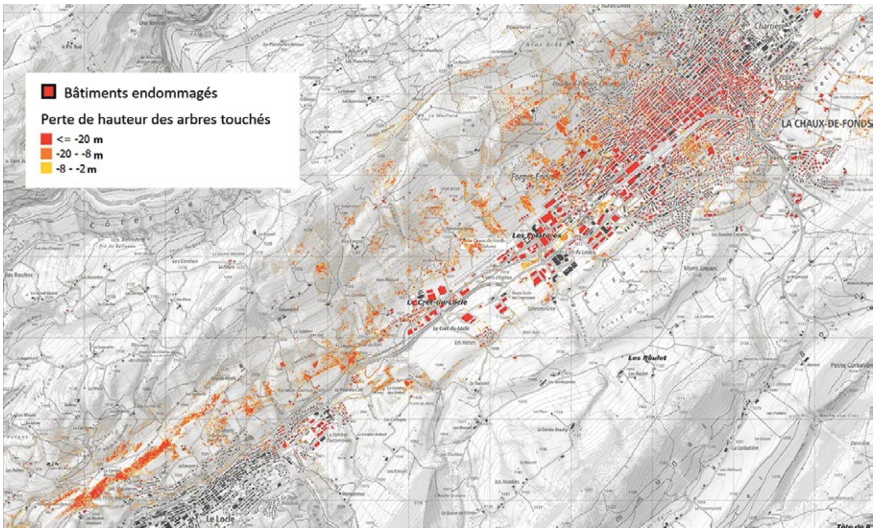

Figure 4: Map of damage, showing the difference between pre- and post-storm canopy models.

Deliverables

The first flight was conducted in an emergency context, with the primary objective of delivering usable data to emergency services as quickly as possible. A 2 cm resolution orthophoto, referred to as a "quick-drop orthophoto", was delivered on July 29 to support the analysis of building and roof damage within urban areas. To accelerate production, the cantonal digital terrain model (DTM) provided by SITN was used for orthorectification, allowing image processing to proceed without waiting for lidar data integration.

In addition, the use of a high-performance inertial measurement unit (IMU) enabled the acquisition to be processed without ground control points, significantly reducing production time. The very high spatial resolution of 2 cm was intentionally selected to allow detailed identification of roof damage, down to the level of individual tiles.

In a second phase, lidar data processing enabled the production of a true orthophoto with improved geometric accuracy. Data acquired during the August 10 flight was subsequently integrated to generate a four-band RGB-NIR orthophoto at 10 cm resolution covering the surrounding forest areas, delivered on August 16.

In total, the acquisition campaigns produced nearly 15,000 images and approximately 25 billion lidar points, representing a total data volume of approximately 3 TB

Data processing, analysis, and dissemination

SITN was responsible for processing, analyzing, and disseminating the datasets acquired during the three airborne campaigns carried out by Sixense Helimap. This work required exceptional coordination and close collaboration with operational users and technical partners. In parallel, SITN collaborated with Flai[2] to perform automated classification of lidar point clouds using a cloud-based platform integrating artificial intelligence. This approach reduced processing time by several weeks compared to conventional workflows.

A primary objective was to provide the most relevant datasets to users as rapidly as possible. Several challenges had to be addressed simultaneously, including prioritizing user needs, coordinating external partners (Sixense Helimap, Flai, and the Federal Office of Topography — swisstopo[3]), managing very large data volumes, selecting processing algorithms optimized for speed and reliability, and rapidly developing customized applications adapted to operational requirements.

The main output products included:

- Rapid publication, four days after the storm, of an orthophoto dedicated to security and emergency services
- Collaboration with swisstopo to obtain high-priority pre-event Swissimage imagery from May 2023, enabling meaningful before-and-after comparisons under similar vegetation conditions
- Development of a dedicated geoportal for the forestry service (SFFN) to support intervention planning and safety management
- Creation of a GIS application for the cantonal insurance institution (ECAP) to locate, record, and monitor more than 3000 damaged buildings.
- Development of QGIS-based operational applications for the emergency services command center (SIS) to visualize raw imagery and monitor safety interventions in near real time

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[2] https://www.flai.ai/

[3] https://www.swisstopo.admin.ch/en

- Creation of a simplified geoportal for decision-makers and MeteoSwiss to facilitate analysis of the phenomenon and comparison of pre- and post-event conditions[4]
- Publication of all datasets on the cantonal 2D geoportal[5] and the 3D lidar geoportal[6]

Particular emphasis was placed on high-density lidar data, which proved to be a major asset for assessing vegetation damage. To facilitate comparisons between pre- and post-event conditions, SITN relied on its cantonal lidar survey acquired in spring 2022, with a density exceeding 100 ppsm. The availability of national Swissimage 2023 imagery, prioritized by swisstopo, was essential for meaningful comparison, as earlier imagery was either outdated or acquired outside the leaf-on vegetation period, making canopy assessment difficult.

Several lidar-based analyses were performed to support both large-scale visualization of damage and detailed analysis at the individual tree level. The main products included:

- Digital canopy models generated before and after the storm, together with their differences to quantify vegetation loss (**Figure 4**).
- Nearest-neighbor analysis of pre- and post-event lidar point clouds, enabling detailed three-dimensional visualization and cross-sectional analysis of damage at the individual tree scale (**Figures 5** and **6**).

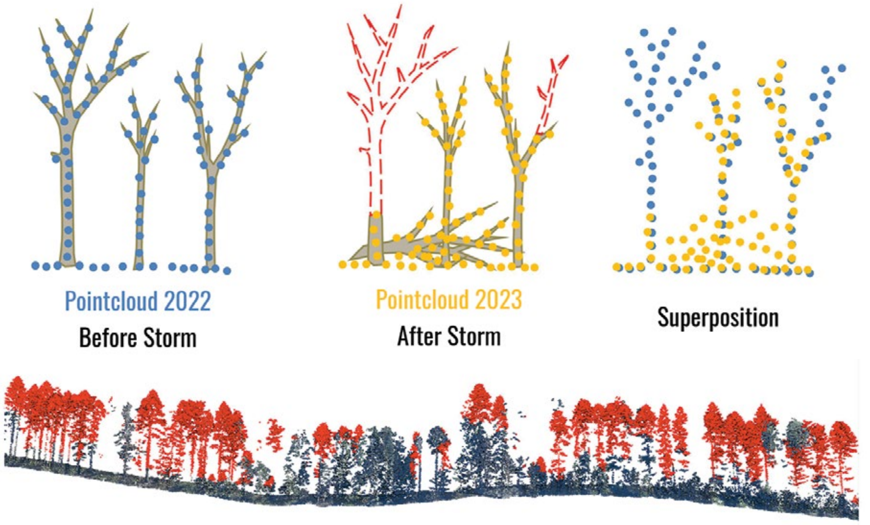

Figure 5: Cross-section view showing the pre-event (2022) points colored in red where storm damage occurred in 2023.

Figure 6: 3D lidar geoportal (Potree-based) highlighting damage to trees across the entire affected area.

- Classified point clouds and maps of standing and fallen tree trunks (**Figure 7**).

Operational feedback and user perspectives

Following the delivery of geospatial products and applications, SITN conducted a feedback survey among the main actors involved in crisis management, to assess the operational value of the data and tools developed, and to obtain input to adapt the rapid mapping strategy for future events. The main conclusions are summarized below.

Fire department command center (SIS). The geoportal integrating orthophotos and the intervention monitoring application developed in QGIS significantly improved operational efficiency during crisis management. The orthophotos

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[4] https://sitn.ne.ch/web/t240723/t240723.html (t240723 is the code name for the storm on July 24, 2023)

[5] https://sitn.ne.ch/s/t240723

[6] https://sitn.ne.ch/lidar/t240723.html

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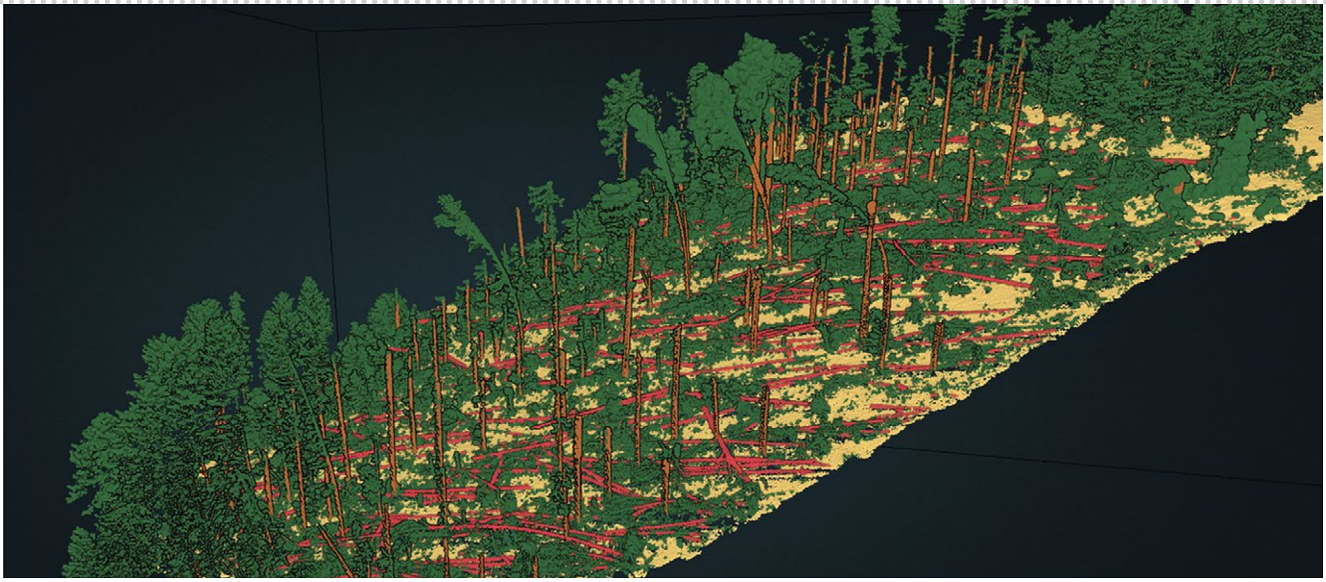

Figure 7: Mapping forest damage: AI classification of standing and fallen tree trunks (SITN-Flai collaboration).

provided an immediate overview of the situation affecting approximately 3000 damaged roofs. Without aerial surveys, assessment would have required the deployment of ladder trucks sector by sector, resulting in substantial delays and resource mobilization.

The solutions developed enabled real-time monitoring of safety interventions, providing a clear overview of completed and pending work. Information related to damage types, intervention status, and responsibility for corrective actions could be centrally managed. The system also facilitated follow-up interventions, as additional windstorms required repeated inspections of previously secured roofs.

Finally, the recorded information proved valuable for conflict management, allowing the fire department to respond objectively to claims regarding allegedly inadequate interventions.

Cantonal Insurance Institution – ECAP. The geoportal developed by SITN enabled ECAP to carry out its assessment mission objectively, while limiting the need for additional field investigations. The data supported preventive safety measures in cases where building elements remained at risk of falling and enabled more accurate calculation of compensation through comparison of pre- and post-event conditions.

The overview provided by orthophotos also facilitated internal organization, including the allocation of affected sectors among insurance experts. The photographic surveys contributed directly to estimating overall damage costs and identifying areas requiring additional safety measures, particularly ahead of winter conditions.

Department of Wildlife, Forests, and Nature (SFFN). The combination of orthophotos and lidar data proved essential for managing and securing affected forest areas. Rapid processing of lidar data, even prior to full classification, allowed immediate identification of areas with significant vegetation height loss and provided a first estimate of the spatial extent of forest damage. Given the scale of the affected area, such an overview would not have been achievable using field observations alone.

Geospatial data significantly supported intervention planning, including accessibility assessment, identification of temporary storage areas, and prioritization of interventions in protective forests and frequently visited public areas. The placement of access restrictions and safety measures was largely based on lidar-derived information.

At a later stage, the canopy height difference model enabled a more precise estimation of the volume of damaged timber. Initial estimates made immediately after the storm suggested approximately 150,000 m^3 of damaged wood, whereas lidar-based analysis refined this estimate to approximately 50,000 m^3. Both lidar data and orthophotos also proved valuable communication tools for conveying the scale and nature of the damage.

The sequence of three acquisition campaigns further enabled the identification of suspicious tree felling activities. The quality and temporal consistency of the datasets, combined with field verification, provided a high level of confidence in the analysis.

The rapid integration of operational layers into the geoportal, including intervention zones, wood storage areas, and work progress, enabled efficient coordination of logging operations. Up to four logging teams, transport operations, and forestry supervision activities were coordinated efficiently from a central location, significantly reducing field travel and communication overhead.

Green spaces department of the City of La Chaux-de-Fonds. Post-event geospatial data was primarily used to assess reported damage and monitor unjustified tree removal carried out after the emergency phase. The availability of aerial imagery acquired shortly before and after the storm allowed clear differentiation between storm-related losses and subsequent interventions.

Lidar data, including point clouds and canopy models illustrating vegetation loss, played a decisive role in identifying the most affected areas. These datasets are now also being used to support long-term urban reforestation strategies and park reconstruction projects. The 3D photogrammetric reconstruction model generated from oblique imagery is currently used in planning future planting and landscape redesign.

MeteoSwiss. The availability of high-resolution geospatial data represented a major asset for understanding the event[7] and will be equally valuable for future extreme weather events. The before-and-after datasets provided comprehensive spatial coverage and sufficient resolution to analyze the geometry of damage patterns, which was essential for distinguishing between linear and rotational wind effects.

Visualization capabilities provided by the SITN platform and the canopy height difference layer were particularly valuable for identifying areas with the most significant structural changes following the event.

Conclusion

In extreme situations, rapid documentation of post-event conditions is essential not only for effective crisis management but also for preserving evidence of the phenomenon before restoration and cleanup operations alter or remove visible traces. Accurate and timely geospatial documentation makes it possible to better understand event dynamics retrospectively and to improve future risk assessment and mitigation strategies.

The experience gained during the storm of July 24, 2023 demonstrated that rapid deployment of airborne acquisition systems, combined with efficient data processing workflows and close collaboration between institutions, constitutes a decisive factor in successful crisis response. The ability to produce and disseminate multiple complementary geospatial datasets within a very short timeframe significantly improved situational awareness and operational coordination among stakeholders.

This event occurred in a broader context marked by several major natural hazards in Switzerland in recent years, including flooding of the Rhône in June 2024 (damage in excess of CHF 200 million), the impressive collapse of the Birch Glacier in May 2025, which wiped the village of Blatten off the map (~CHF 300 million damage). Total natural hazards damages for 2024 are estimated at nearly 1 billion Swiss francs, mainly in June. In such situations, the complementary roles of swisstopo's Rapid Mapping service and high-resolution airborne mapping solutions, such as the combined orthophoto, oblique imagery, and lidar approach presented in this article, have proved particularly effective.

Through this exceptional storm, SITN significantly strengthened its expertise in crisis management and further developed its technical infrastructure and operational workflows in response to evolving environmental challenges. Since 2019, the recurrence of major natural events approximately every two years has confirmed the necessity of maintaining rapid-response geomatics capabilities.

After testing several acquisition configurations in emergency mapping contexts, the combined use of orthophotos, oblique imagery, and lidar has proved especially efficient, with each data source providing complementary and essential information. Feedback from operational users clearly demonstrates the added value of geomatics in crisis management, from emergency response and insurance assessment to forestry management and scientific analysis.

Acknowledgements

SITN wishes to acknowledge the strong commitment and expertise of its partners at Sixense Helimap, Flai, and swisstopo, as well as the operational users who readily adopted the geospatial data and services developed under exceptional time constraints.

Marc Riedo is head of the GIS center for the canton of Neuchâtel (SITN). **Matthew Parkan** is a geomatics engineer at the GIS center for the canton of Neuchâtel. **Julien Vallet** is director and founder of Helimap Sixsense. **Hugues Fournier** is deputy director of Helimap Sixsense. **David Ulrich** is project manager at Helimap Sixsense. **Gildas Allaz** is the geomatics manager for the city of La Chaux-de-Fonds.

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[7] https://sitn.ne.ch/s/meteosuisse

Smart Pixels: The Building Block for Next Evolution of Digital Twins

A revolutionary change of philosophy and architecture is required to take digital twins beyond visualization and fulfill their promise.

This article introduces a transformative concept of Smart Pixels as the building blocks of nextgeneration digital twins. I explore how Smart Pixels are poised to revolutionize design, analytics, and decisionmaking for built environments, signaling the emergence of a new era in geospatial technology. This forward-thinking article is intended for a wide audience within the geospatial mapping community, engineering, and software manufacturing, as well as industry leaders, technology strategists, and innovators. Although the article presents an innovative approach aimed at enhancing the performance and management of digital twins, the responsibility for optimizing hardware configurations and memory architecture ultimately rests with engineers and system architects. Their expertise will be crucial in translating these conceptual advances into practical, efficient implementations within real-world systems.

BY QASSIM **ABDULLAH**

Rethinking the digital twin: why the future depends on the smart pixel

For years, the concept of digital twins has captivated professionals in planning, engineering, and operations, promising dynamic, interactive representations of real-world environments. The prevailing vision imagines digital twins as sophisticated platforms for simulation, optimization, and strategic insight. Yet, despite rapid advances in visualization and enthusiastic adoption across industries, most digital twins remain stuck in a paradigm of static, visually stunning 3D models. These

representations may dazzle on screen, but their lack of integrated intelligence and rich, actionable data has limited their practical impact.

The challenge is not one of technological capability; it is a matter of architectural evolution. At the heart of true transformation is the Smart Pixel—a groundbreaking construct that reimagines each pixel in a digital twin as an intelligent micro-container. Within each Smart Pixel resides the "information DNA" of a location: its physical state, behavioral history, real-time measurements, and contextual metadata. This architectural shift turns digital twins from impressive visualizations into powerful analytic engines, enabling real-time decision support and predictive capabilities that were previously out of reach.

Beyond surface-level visualization: the intelligence gap

To unlock the full value of digital twins, systems must transcend mere visual fidelity. A genuine digital twin must:

- Process live updates
- Map precise measurements to specific locations
- Track dynamic changes over time
- Integrate data from multiple domains seamlessly
- Connect disparate information sources and support predictive models that forecast future conditions.

Current digital twins, however, often fall short. Most are built from photorealistic 3D renderings, fragmented GIS layers, isolated sensor feeds, and static lidar point clouds. Occasionally, they include tables of attributes that provide some context but little interactivity. These elements operate as silos, lacking a unified data structure or a mechanism to synchronize and update all information relevant to a single location. The result is a system that functions primarily as an advanced viewer, not as an intelligent, analytic platform.

Smart pixels: The foundational DNA of digital twin

The Smart Pixel introduces a paradigm shift. More than a simple graphical element or point in space, each Smart Pixel is a multidimensional container. It aggregates everything known about precise location, from geospatial attributes and sensor readings to behavioral trends and historical context. This comprehensive approach binds together previously fragmented data sources, enabling seamless updates, holistic analysis, and meaningful interactivity.

With Smart Pixels at the core, digital twins evolve into unified platforms that not only mirror the physical world but also understand and anticipate its changes. This new architecture empowers organizations to model scenarios, optimize operations, and drive innovation with unprecedented accuracy and agility. By embedding intelligence at the pixel level, digital twins become dynamic engines of transformation—poised to reshape industries and redefine what's possible in the digital representation of our world.

The challenge: digital twins lack true intelligence

For a digital twin to deliver meaningful value, it must do far more than mirror the physical world with visual fidelity. The essence of a genuine digital twin lies in its ability to process real-time or near-real-time updates, incorporate precise physical measurements mapped to specific locations, and track dynamic changes over time. Additionally, it demands seamless integration across multiple domains—bridging data from disparate sources—and must enable predictive modeling to anticipate future scenarios.

Yet the reality for most digital twins today is starkly different. They typically consist of impressive, photorealistic 3D models, a patchwork of GIS layers that are only loosely connected, isolated streams from various sensors, and static lidar point clouds. Occasionally, these are supplemented by attribution tables that add some context but little interactivity.

While these elements may coexist within a single system, they function largely in silos. There is no unified data structure binding them together, and each component references the real world in its own way, disconnected from the others. There is no mechanism to store, update, or bring together the full spectrum of information about a specific location—be it a stretch of road, a building, or a shoreline—within a shared, consistent framework.

This fragmentation means that digital twins currently serve more as advanced viewers than as intelligent, analytical systems. Without true integration and interaction between their components, digital twins fall short of their transformative potential.

Comprehensive data DNA within each smart pixel

A Smart Pixel represents the foundational element of an advanced digital twin ecosystem. Unlike a simple pixel in an image or a lone point within a point cloud, a Smart Pixel (**Figure 1**) functions as a dynamic container of rich, multidimensional data, encapsulating every available detail about a specific spatial location. Each Smart Pixel contains its own data DNA, such as:

- **Spatial attributes:** Each Smart Pixel records precise three-dimensional geographic coordinates—including latitude, longitude, and elevation—along with the coordinate reference system and associated geometric uncertainty.
- **Physical and environmental parameters:** The Smart Pixel stores real-time measurements such as temperature, humidity, soil moisture, air quality indices, vegetation vitality, and water depth or turbidity, reflecting the environmental state of its location.
- **Spectral and imaging information:** Smart Pixels capture a spectrum of imaging data, from standard RGB values to multispectral and hyperspectral signatures, as well as thermal properties and reflectance characteristics, enabling detailed remote sensing analysis.
- **Sensor metadata:** Every Smart Pixel maintains metadata about the sensors and platforms that contributed its data—whether from UAS, satellites, or IoT devices—including the time of data acquisition, sensor geometry, calibration details, and lineage or accuracy metrics.
- **Semantic attributes:** It contains classifications—such as ground, building, vegetation, or roadway—alongside material type, condition, and risk assessments, adding meaningful context to each location.

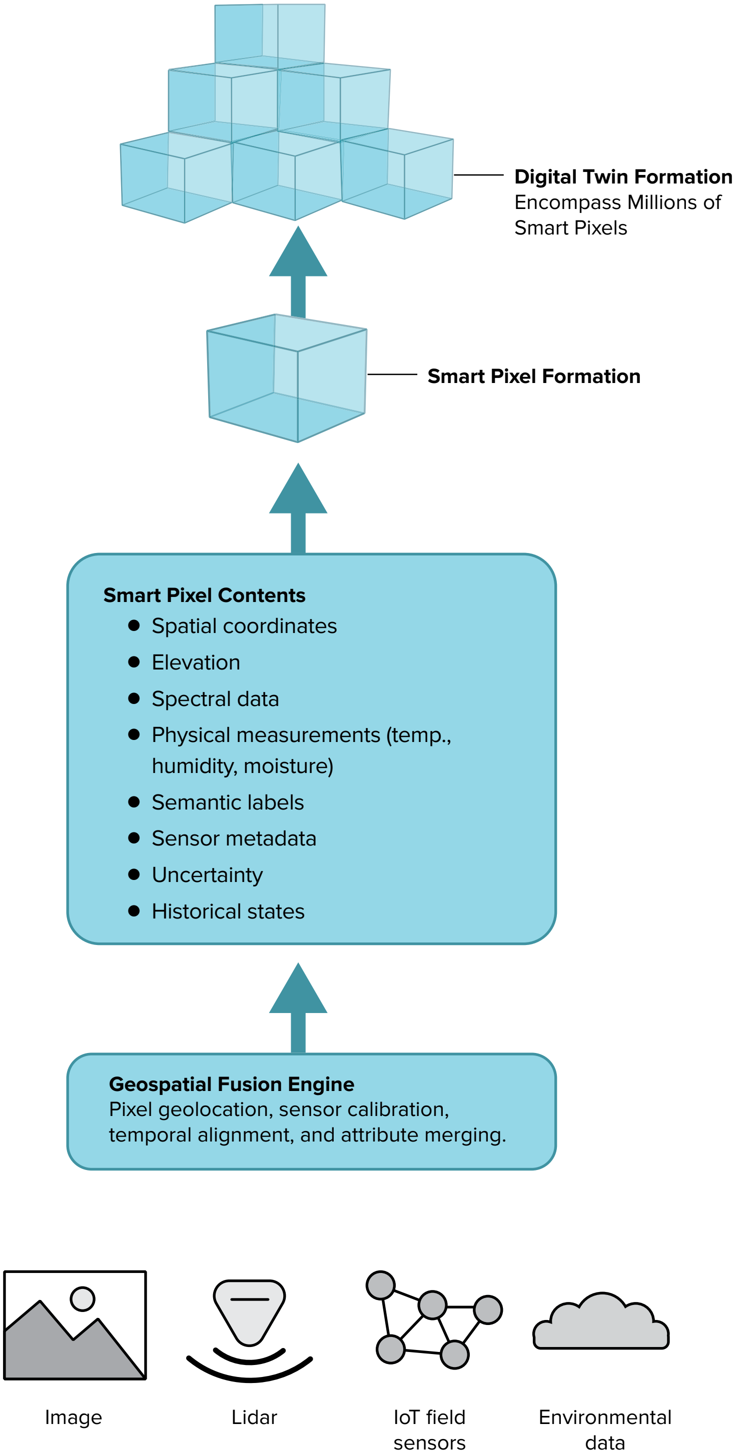


Figure 1: The role of Smart Pixels in a digital twin.

- **Temporal history:** Smart Pixels record previous states, supporting trend analysis and change detection, and incorporate updates from predictive models to anticipate future scenarios.
- **Connectivity to external models:** Each Smart Pixel can link to external simulation models—including hydrodynamic, traffic, structural, or climate models—and respond to event triggers and rules that manage how updates propagate across the digital twin.

In summary, a Smart Pixel functions as a living, evolving data cell. It continuously aggregates and updates everything known about its spatial position, enabling the digital twin to operate with intelligence and analytical depth at the most granular level. This transformative capability allows digital twins to move beyond static representations, supporting real-time decision-making and predictive analytics for complex environments.

Why building digital twins on smart pixels is essential

1. **Digital twins must be analytical, not merely visual:** Without Smart Pixels, digital twins are essentially 3D scenes with bolt-on analytics. With Smart Pixels, every location is an analytical object. Traditional digital twins that lack Smart Pixels are limited to being visually rich 3D representations with analytics layered on *post hoc*. In contrast, when constructed with Smart Pixels, every spatial location is transformed into an intelligent analytical entity. This means that analysis is embedded at the most granular level, making the digital twin inherently capable of advanced computations and insights rather than relying on external analytical modules.
2. **Facilitates real-time updates and advanced multi-sensor integration:** Smart Pixels empower digital twins to assimilate data from a wide array of sources—satellites, drones, IoT sensors, and lidar—seamlessly and in real time. They enable automatic resolution of discrepancies among different sensor inputs and support time-sensitive data fusion, where new information can either update or enhance previous states. The result is a continually synchronized, accurate, and up-to-date digital representation of the environment.
3. **Enables robust predictive modeling:** With each Smart Pixel encapsulating detailed physical properties, environmental conditions, and a historical timeline, sophisticated models—such as climate forecasting, flood risk simulations, structural health assessments, and traffic flow analyses—can operate directly at the pixel level. This pixel-centric intelligence allows for highly localized, precise, and actionable predictions that are grounded in rich contextual data.
4. **Unifies disparate data sources:** Rather than maintaining multiple isolated layers of information, the Smart Pixel framework serves as a comprehensive and unified data backbone. All relevant attributes become indexed, searchable, and analyzable within a consistent structure, breaking down silos and streamlining data management across the digital twin ecosystem.
5. **Empowers artificial intelligence and autonomous systems:** Artificial intelligence models achieve optimal performance when data is well-structured, metadata is standardized, uncertainties are quantified, and attributes are precisely localized. Smart Pixels provide this ideal data environment, enabling AI agents to detect anomalies, recognize complex patterns, conduct real-time simulations, and optimize operational strategies within digital twin environments.
6. **Smart pixels offer cloning and interoperability:** Once a Smart Pixel has been created and populated with its rich set of attributes, it can be replicated and distributed to other digital twins managed by different organizations, agencies, or even across state lines. This cloning capability ensures that valuable, high-fidelity data does not need to be re-created from scratch, eliminating redundant efforts and maintaining a single, authoritative source of truth. By sharing cloned Smart Pixels, organizations can maximize the value of their information, streamline collaboration, and fully leverage existing resources, fostering more efficient and unified digital twin ecosystems.
7. **Smart pixels adapt to spatial scale:** The spatial resolution of Smart Pixels within a digital twin is tailored to match the specific requirements and scale of the environment being modeled. This means that Smart Pixels can dynamically adjust in size—offering denser, higher-resolution

coverage where detail is critical, and coarser, larger pixels where less granularity is needed. For instance, in the case of a digital twin representing an entire ocean, Smart Pixels near the coastlines would be much smaller and more detailed to capture the complex and rapidly changing conditions of these regions. As the digital twin expands into deeper ocean areas, where environmental changes are generally less pronounced and high-resolution data is less essential, the Smart Pixels become larger and less detailed. This strategic flexibility ensures that computational and storage resources are used efficiently, concentrating processing power where it matters most while maintaining comprehensive coverage across the entire modeled environment.

The smart pixel will transform the future of mapping

Digital twins anchored with Smart Pixels evolve far beyond traditional 3D objects or layered GIS datasets. Instead, they become dynamic engines for simulation, providing a foundation for real-time observation, advanced sensor integration, predictive analytics, and holistic system intelligence. The Smart Pixel framework empowers a digital twin to function as:

- A robust simulation engine that can replicate and analyze complex scenarios within the built or natural environment.
- An always-on monitoring system, continuously reflecting real-world changes as they happen.
- A seamless multi-sensor fusion platform, integrating data from satellites, drones, IoT devices, and more, in real time.
- An environment for predictive analytics, enabling localized, data-driven forecasts and actionable insights.
- A digital nervous system that interconnects and manages the flow of information across every spatial point.

This innovative architecture marks a critical shift for the industry, moving from:

- Simple 3D visualization to deep 3D understanding
- Basic data aggregation to true data intelligence
- Static mapping to dynamic, context-aware modeling

Ultimately, the Smart Pixel establishes itself as the essential backbone of intelligent digital twins—capable of encapsulating every facet of real-world information for any given location. This approach ensures that digital twins are not merely visual representations but comprehensive analytical platforms, supporting advanced computations, real-time operations, and informed decision-making at every scale.

Conclusion: Redefining the digital twin's foundation

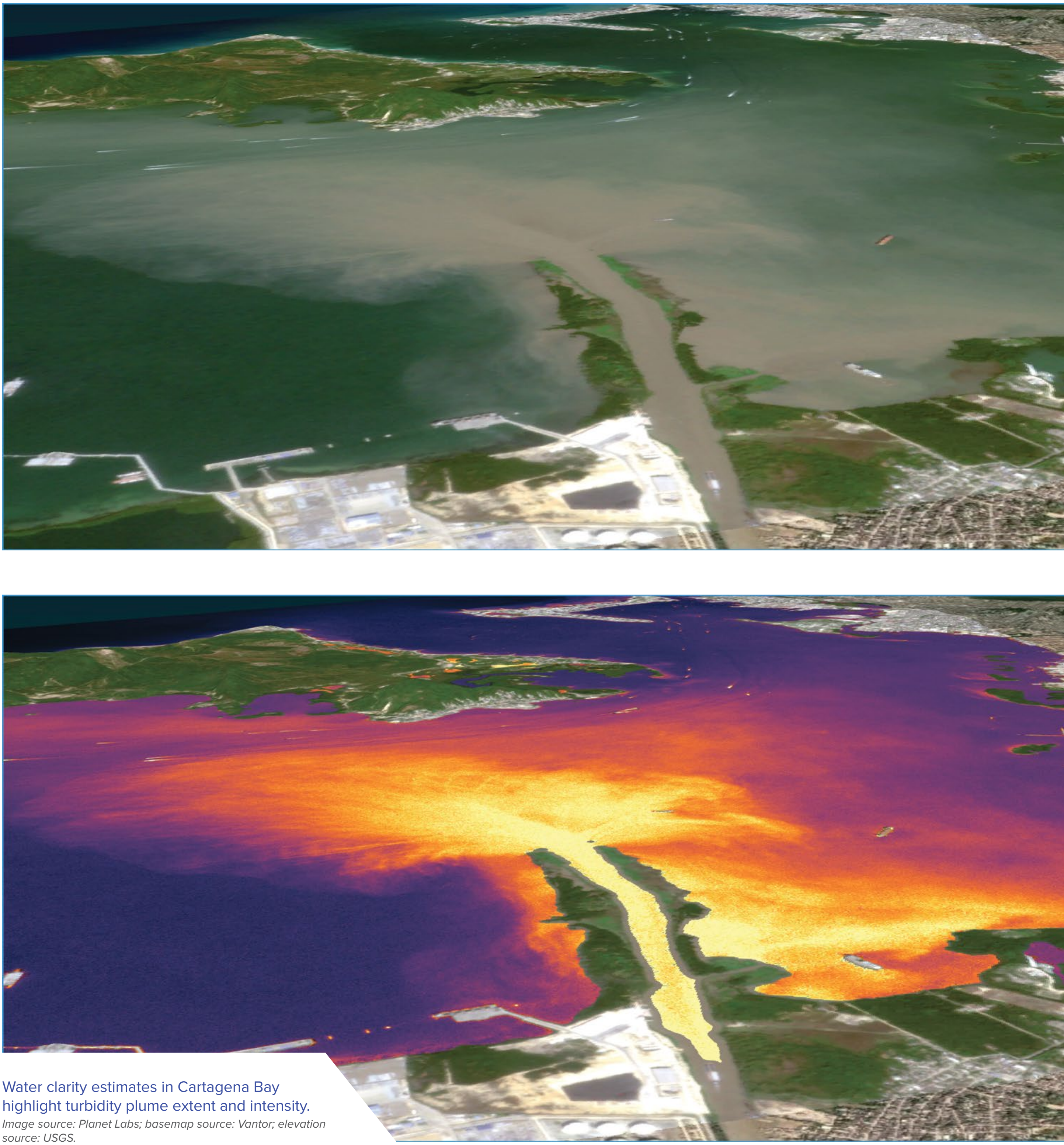
To realize the transformative potential of digital twins successfully, the geospatial industry must adopt the Smart Pixel as the foundational element of its next-generation platforms. The Smart Pixel is more than just a visual marker—it encapsulates the complete "DNA" of a location, including its geometric structure, physical characteristics, environmental variables, sensor data history, and semantic context.

The digital twins of tomorrow will be distinguished not by their ability to render 3D images, but by the depth and intelligence of their data architecture. By building upon the Smart Pixel, we shift from simple visualization to comprehensive data modeling, enabling digital twins to serve as dynamic, analytical engines that reflect and interpret every nuance of the real world.

Embracing the Smart Pixel marks a pivotal evolution. It transforms digital twins into powerful, context-aware platforms—capable of supporting real-time analysis, predictive modeling, and informed decision-making at any scale. This is the new backbone upon which the future of intelligent digital twins will be built.

Note: This article is running in *Photogrammetric Engineering & Remote Sensing*, *LIDAR Magazine*, and *Geo Week Newsletter*.

Woolpert Vice President and Chief Scientist **Qassim Abdullah, Ph.D., PLS, CP**, has more than 45 years of combined industrial, R&D and academic experience in analytical photogrammetry, digital remote sensing, and civil and surveying engineering. He has been instrumental in developing the ASPRS Positional Accuracy Standards for Digital Geospatial Data, versions 1 and 2. When he's not presenting at geospatial conferences around the world, Qassim teaches photogrammetry and remote sensing courses at the University of Maryland and Penn State, authors a monthly column for the ASPRS journal PE&RS, and mentors R&D activities within Woolpert.



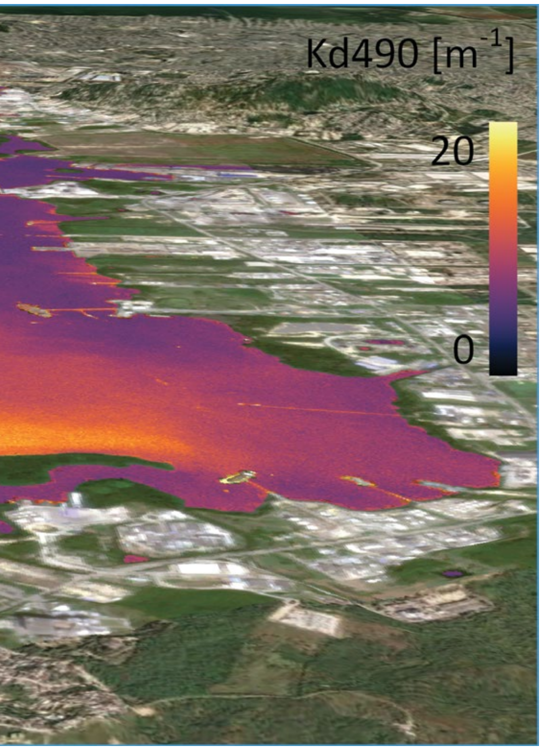
Water clarity estimates in Cartagena Bay highlight turbidity plume extent and intensity.

Image source: Planet Labs; basemap source: Vantor; elevation source: USGS.

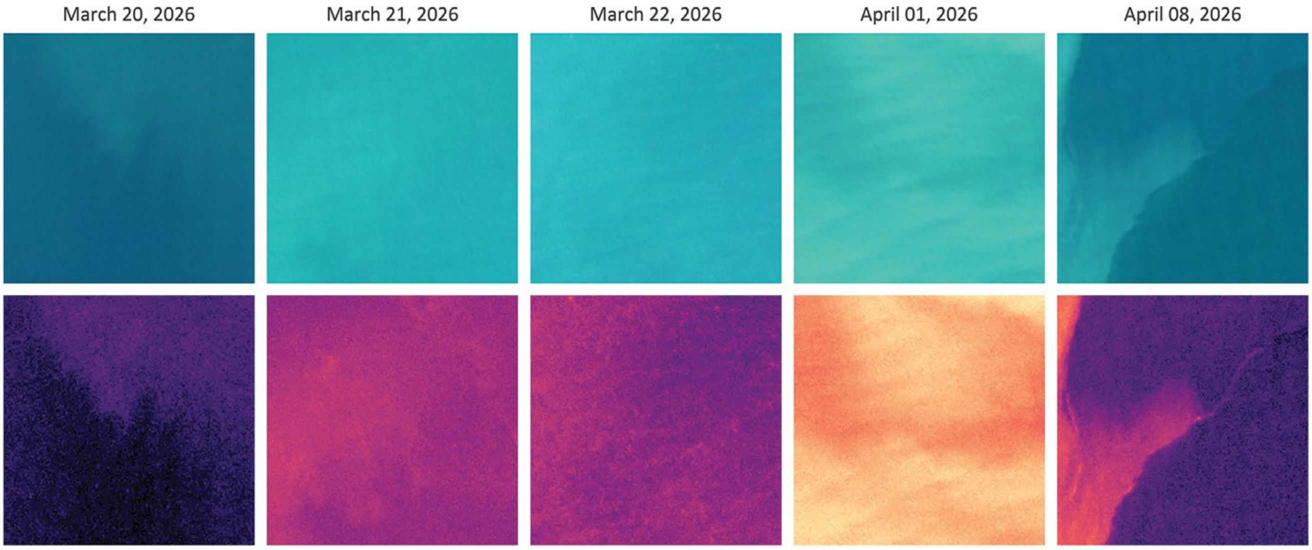
Improving Topobathymetric Lidar Planning and Operations with Satellite-Based Water Clarity Monitoring

TCarta's water clarity dashboard, HydroIQ, provides daily measurements contextualized against historical trends to inform flight operations, project timelines, and reflight decision-making.

BY EMILY **FRENCH**



Topobathymetric project success depends on aligning flight operations, including pilot schedules, maintenance windows, and calibration requirements, with short windows where weather and sea-state conditions are optimal. To assess water clarity and sea-state, flight operators and project managers rely on reconnaissance flights and field mobilization, which are costly and have limited geographic coverage. Satellite-based water clarity monitoring addresses these limitations by providing comprehensive coverage of entire waterbodies and coastlines at almost daily frequencies for a fraction of the cost of traditional survey methods. When daily measurements are contextualized within historic trends, the resulting insights improve topobathymetric



Natural color satellite images (top row) and corresponding Kd490 estimates (bottom row) for a 1 km^2 monitoring site off the coast of New Zealand. By monitoring a single site over time, users can watch turbidity plumes emerge and disperse in response to rain, winds, and near-shore currents.

Image source: Planet Labs.

data quality, lower operational costs and minimize carbon footprints.

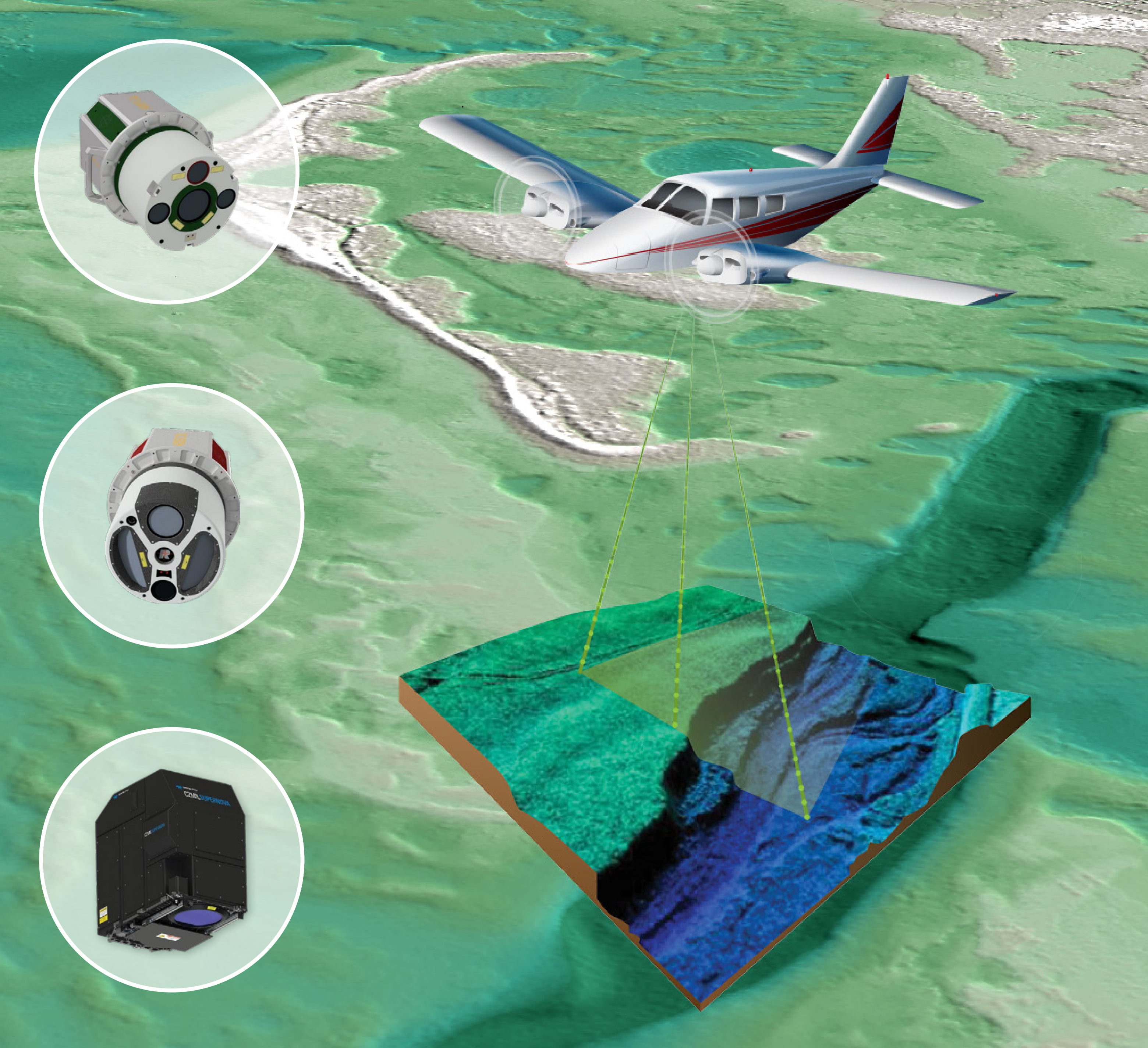
The advantages of satellite imagery for water clarity monitoring

Modern satellite constellations provide unparalleled spatial and temporal coverage that enables both historical and near-daily water clarity assessment in a wide range of aquatic environments ranging from open ocean to rivers and lakes. In coastal environments, water clarity derived from the Sentinel-3 Ocean and Land Color Instrument (OLCI) is the gold standard. Sentinel-3 OLCI observations have a 300 m spatial resolution, are available within three hours of capture at near-daily frequency and have a historical archive reaching back 10 years to 2016. Because Sentinel-3 OLCI was designed specifically for aquatic remote sensing, it boasts a uniquely high signal-to-noise ratio and 21 spectral bands from 400 to 1200 nm. This design facilitates atmospheric correction in complex coastal environments as well as enhanced sensitivity to water constituents including suspended sediments, chlorophyll-a, and colored dissolved organic matter.

Given that Sentinel-3 observations are freely available and provide exceptionally high-quality water clarity estimates, they are almost always the best choice for coastal monitoring; however, for projects in rivers, ports, or small inland waterbodies, 300 m Sentinel-3 observations may be too coarse. For these applications, commercial imagery from the 3 m PlanetScope constellation is an appropriate substitute. Like Sentinel-3, PlanetScope imagery is available shortly after capture with near-daily frequency and has a comprehensive historical archive reaching as far back as 2020. With eight spectral bands ranging from coastal blue to near infrared, PlanetScope provides both the spatial and spectral resolution required for monitoring water clarity in optically complex waters where detailed spatial resolution is required.

TCarta’s technology and approach

Daily water clarity measurements from either Sentinel-3 or PlanetScope contextualized against historical trends are the foundation of TCarta’s water clarity dashboard service, HydroIQ. HydroIQ’s analysis and displays are custom-built to support three distinct topobathymetric lidar project phases: initial scoping and project planning, day-to-day flight operations, and reflight decision-making. Importantly, the platform is equipped to facilitate rapid, straightforward interpretation for non-technical users and, at the same time, provide detailed trend information to data specialists.



APPLYING THE LATEST TURNKEY SOLUTIONS AND REMOTE SENSING TECHNOLOGY
FROM DATA ACQUISITION TO CLIENT DELIVERY

Jason Dolf, CP, CMS
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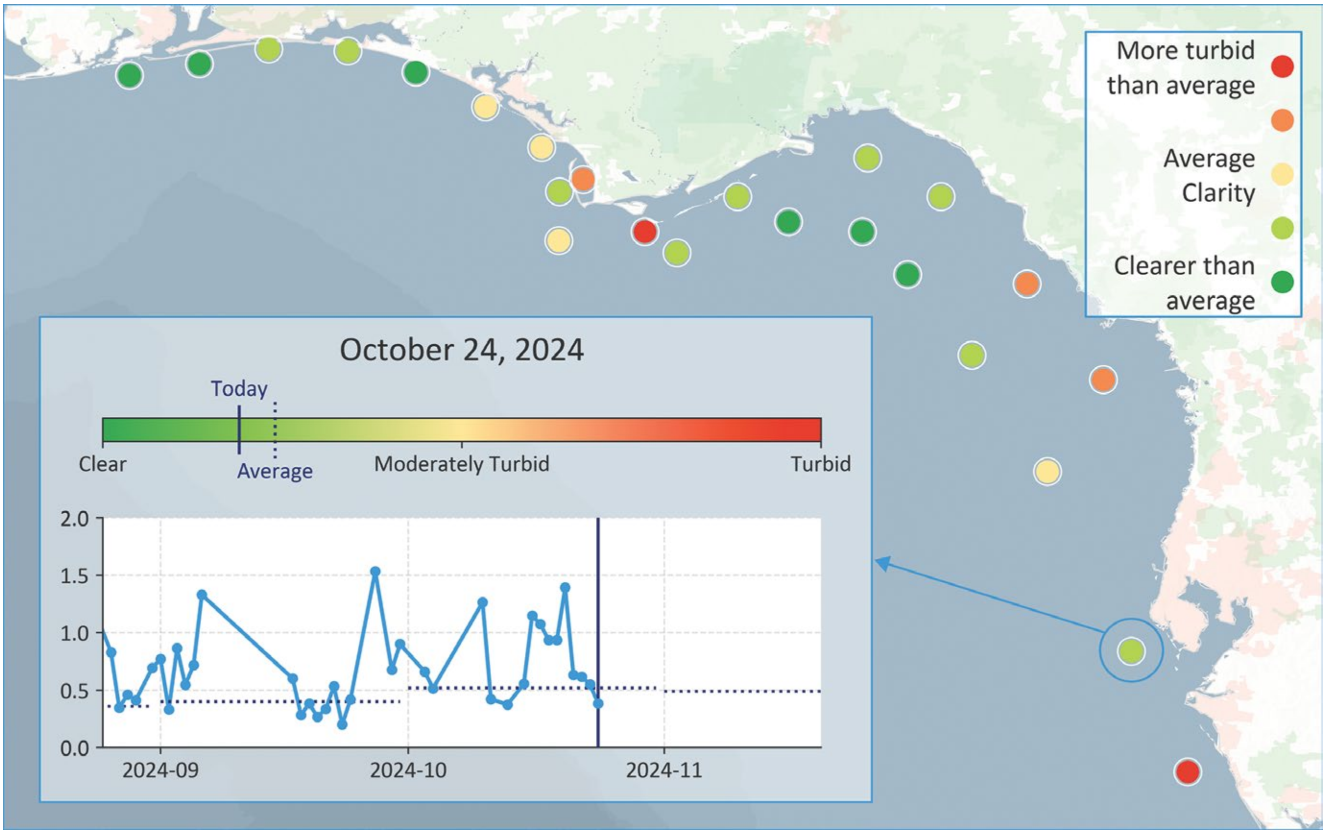
The primary water clarity parameter behind HydroIQ is the diffuse attenuation coefficient at 490 nm, often referred to as Kd490, which quantifies the rate at which blue light is scattered and absorbed as it moves through the water column. As values increase, water clarity decreases. Complementary parameters may include turbidity, secchi depth, and, in complex waters, chlorophyll-a concentration and the backscattering coefficient at 490 nm.

In aquatic environments, complex atmospheric conditions driven by evaporation and rapidly changing aerosol concentrations present a persistent challenge to satellite-based water clarity monitoring. TCarta addresses these challenges by applying rigorous atmospheric correction to produce accurate and consistent retrievals across a wide range of acquisition conditions and time periods. In addition to atmospheric correction, detailed cloud masking makes it possible to use observations where just a small portion of the monitoring area is visible. This significantly increases the total number of usable observations and makes water clarity monitoring possible even in persistently cloudy environments.

Beyond the challenges associated with atmospheric conditions, coastal waters are highly dynamic and optically complex. Water clarity, governed by suspended sediments and organic matter concentrations, shifts considerably across environments and changes rapidly due to rainfall, tidal cycles, and wind events. In this context, water clarity parameters are estimated using methods tailored to site-specific conditions, ranging from band ratios and semi-empirical algorithms to machine learning and in-water radiative transfer models. Where robust in-situ data is available, location-specific algorithms can be developed to improve accuracy and extend the spatial and temporal applicability of direct measurements.



Daily water clarity relative to the monthly average for monitoring sites in Florida. Green points represent sites that are clearer than average; red shows sites where recent conditions are more turbid than expected. The site pop-up provides additional context. This example assumes that today's date is 24 October 2024.

Basemap source: Esri.

Historical insights support project planning

Even before a project begins, historical water clarity data reveal site-specific seasonality and overall turbidity baselines which can be used to inform bid submission, client expectations, and resource planning and staging. Water clarity often follows predictable seasonal patterns driven by factors such as storm frequency, snowmelt, and river discharge. Hence understanding these patterns is essential for structuring project timelines around windows when conditions are mostly likely to support successful collection. To address this, TCarta calculates the average water clarity for each month across six to ten years, depending on data availability. The resulting monthly estimates are insulated against year-to-year fluctuations and reveal when, on average, conditions are optimal for bathymetric lidar collection.

Beyond seasonality, historical averages highlight persistently turbid, or, conversely, clear locations. In an industry where water clarity specifications are often based on optimal or manufacturer-rated conditions, real-world site-specific information facilitates strategic operational sequencing and sets realistic client expectations for the most challenging sites. Historical water clarity analysis gives project teams key evidence to support conversations with clients from the earliest stages of engagement, including project scoping. Ultimately, the goal is to ensure that specifications reflect what a site can realistically deliver, reducing the likelihood of scope changes, budget overruns, and unmet expectations.

Daily observations streamline operational decision-making

Once a project is underway, HydroIQ helps maximize the quality and depth penetration of surveys by supporting flight decision-making with user-friendly data display and comprehensive daily coverage across the survey area. For this purpose, the dashboard provides two complementary views of daily measurements: absolute water clarity and water clarity relative to the monthly historical average. This dual perspective is particularly valuable because it highlights time-sensitive collection opportunities. For example, the absolute view may identify five sites with acceptable clarity on a given day. The relative view adds important context, revealing that four of those sites are consistently clear and could be surveyed at any point during the project window, while the fifth is experiencing unusually favorable conditions relative to its monthly average. In this case, the relative view helps identify an ephemeral opportunity that could be missed without the kind of comprehensive view satellite-based data can provide. Conversely, HydroIQ can flag sites where conditions may appear acceptable in absolute terms but are actually more turbid than their historical average. In this case, delaying collection could yield better results. Together, these two perspectives give flight teams a more complete picture of where and when to fly, reducing the risk of collecting data in suboptimal conditions.

Because HydroIQ is designed so that both technical and non-technical stakeholders can engage with the data, it is also a valuable tool for keeping all parties informed and aligned as projects evolve. For clients, the ability to view real-time conditions alongside historical context provides confidence that flight teams are operating efficiently. Shared use of the platform also builds a common understanding of how recent conditions influence project progress and gives clients the opportunity to give input based on both HydroIQ and their own contextual knowledge.

ABOUT TCARTA

TCarta delivers satellite-based hydrospatial intelligence to solve complex challenges in dynamic coastal and aquatic environments. Founded in 2014 and headquartered in Denver, Colorado, TCarta has decades of combined experience in hydrography, geospatial science, remote sensing, and environmental science. To learn more visit www.tcarta.com or email info@tcarta.com.

Water clarity trends guide reflight decisions

Reflight decision-making can have huge implications for overall data quality, project cost, timeline, and carbon footprint. HydroIQ supports reflights by providing site-specific popups that contextualize water clarity on any given day within historical averages and other recent observations. This allows teams to answer key questions such as: were conditions during the initial collection attempt unusually poor, and is there good reason to expect better results by flying again? If HydroIQ shows that conditions at the time of collection were well below the historical average, a reflight is likely to yield improvement. If conditions were already near or above average, the basis for reflight is weaker and the corresponding cost is harder to justify. By framing reflight decisions with both observed and historical contexts, HydroIQ helps teams avoid costly mobilizations with limited benefit while ensuring that genuinely poor collection conditions don't go unaddressed. Furthermore, HydroIQ can be used to communicate the argument for reflight to clients. Rather than relying on qualitative assessments, project teams can point to specific water clarity measurements to build a shared understanding of the likelihood that reflying will improve returns.

HydroIQ supports NV5 and LINZ in New Zealand

Since early 2025, HydroIQ has supported NV5 Geospatial's topobathymetric lidar operations over New Zealand's South Island as part of Toitū Te Whenua, Land Information New Zealand's 3D Coastal Mapping Programme. This program is an ambitious three-year initiative to capture high-resolution elevation and seafloor data across 40% of New Zealand's coastline in support of hazard modeling, infrastructure resilience, and long-term coastal planning. New Zealand presents some of the most challenging survey conditions in the Southern Hemisphere, including sediment-laden surf zones, steep coastal topography and unpredictable weather. In this context HydroIQ has been an essential asset for NV5. With more than 50 sites placed at key river mouths and survey locations, HydroIQ gives NV5's flight teams a persistent, near-daily view of water clarity conditions across the entire survey area, supporting real-time flight decisions and ensuring collection is prioritized when and where conditions are most favorable.

Feedback from LINZ indicated the value of the system. "Ultimately, this service helped improve data quality, lower NV5's operational costs, increase efficiency and minimize the project's carbon footprint," commented Brad Cooper, Senior Hydrographic Surveyor, LINZ.

As the project approaches the end of its second collection season, HydroIQ has increasingly supported reflight decision-making. For NV5, HydroIQ provides the operational context needed to determine whether a reflight is likely to improve returns or confirm that initial results reflect persistent conditions which are unlikely to improve within the project timeline. For LINZ, access to the same data supports informed oversight and clear communication across a technically complex, multi-year programme. According to Colin Cooper, Technical Director, NV5, "TCarta's HydroIQ platform has become a valuable operational tool for our topobathymetric lidar program, providing consistent, data-driven water clarity insights that support planning, flight execution, reflight decisions, and client communication."

Looking ahead

Beyond New Zealand, HydroIQ has been successfully deployed in support of topobathymetric survey operations across a range of aquatic environments, from the coastal waters of Florida to rivers and estuaries in the northeastern United States. At its core, HydroIQ is a flexible platform that can be configured for long-term projects as well as rapid-response deployments for disaster relief and emergency mapping where timely water clarity information can be critical to operational planning. The service is equally applicable to limited-season environments such as the Arctic, where short collection windows make the ability to identify and act on favorable conditions especially valuable.

Moving forward, TCarta plans to integrate river gauge measurements, tides, wind, and precipitation-based predictions into its dashboards, giving teams an even more comprehensive view of factors that impact bathymetric lidar returns. Recent milestones in reducing image latency, including delivery times approaching 13 minutes from capture, point toward a future where near real-time water clarity information is routinely available to flight teams in the field. As these capabilities mature, TCarta will continue to evaluate how emerging sensors and delivery pipelines can be integrated into HydroIQ in a way that balances the operational value of faster information against the cost of commercial imagery, ensuring that monitoring configurations reflect the conditions and requirements of unique projects.

Emily French is a remote sensing analyst at TCarta, where she specializes in water quality monitoring, benthic habitat mapping, and hydrospatial remote sensing research. As an analyst and project manager, she brings expertise in optical and radar image processing, statistical modeling, and scientific programming. Emily holds an MA in earth and environment from Boston University and a BA in geography from Middlebury College. She is passionate about applied science, interdisciplinary research, and science communication.

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Precision and Pace: Lidar's Role in Data Center Delivery

How 3D reality capture supports fast, fault-free hyperscale construction

BY DUANE **GLEASON**

Data center construction has become a defining segment of contemporary infrastructure work. Growth in cloud computing, hyperscale deployments and artificial intelligence workloads is driving demand for new facilities and expansions. According to industry reports, the global data center construction market was valued at $227.6 billion in 2025 and is projected to reach more than $434.7 billion by 2035 (Global Market Insights Inc.), reflecting a 6.8% CAGR over 2026–2035. This reflects ongoing investment driven by the need for digital infrastructure across industries. At the same time, demand

for data center capacity continues to escalate. Market analysis suggests growth rates approaching 20 to 25 percent annually in the United States (McKinsey & Company), particularly where artificial intelligence and cloud deployments are concentrated. Across the US, hyperscalers are developing some of the largest data center hubs ever attempted, with multi-gigawatt campuses spanning thousands of acres. Massive developments are underway for OpenAI, Microsoft, Amazon, Google, and Meta. Investment in the OpenAI Stargate Project alone is projected to be $500 billion over the next four years.

These trends influence how data centers are designed and built. Projects are characterized by dense infrastructure, complex routing of utilities and rigorous quality requirements. In this build context, field measurement and verification must remain both precise and rapid. Construction teams increasingly use 3D laser scanning to meet these requirements.

Tolerances in tight spaces

Modern data centers integrate structural systems, electrical distribution, mechanical plant, cooling equipment and IT racks in highly coordinated assemblies. Each of these components occupies defined spatial envelopes, and small misalignments can create conflicts that complicate installation.

In projects with strict tolerances, traditional measurement techniques can be slow and prone to human error. 3D laser scanning captures millions of points across a site or structure with high resolution. These point clouds provide an exact digital record of existing conditions that can be reviewed in a model-based environment.

By integrating scan data into building information models (BIM), teams can perform detailed comparisons between designed geometry and as-built conditions. This enables identification of discrepancies early, when corrections are still feasible and far less costly than changes made after downstream work has begun.

Accurate reality capture also enables prefabrication of electrical and mechanical assemblies. Scanning structural elements before production ensures that components will fit when delivered, reducing the risk of delays due to mismatches between field conditions and fabricated assemblies.

Coordinated construction in the cloud

A key driver of scanning adoption is its ability to support digital delivery. When teams feed point-cloud data into a common data environment, project stakeholders work from one verified reference that aligns design, fabrication, installation and quality control. In data center projects, this connected workflow is important because trades often operate concurrently. By anchoring design models to current field conditions, teams reduce the likelihood of conflicts emerging during installation, which gives them the confidence to make real-time decisions.

Scanning also improves subcontractor coordination. Trade partners can all access the same high-fidelity data to plan their work. By clarifying responsibilities between disciplines, they maintain quality and avoid schedule disruptions.

Fast-track facilities

Data center construction schedules are typically aggressive. Owners and operators plan facility operations to meet business commitments or service rollouts. Delayed openings can have significant financial implications. Often, schedules allow little room for remedial work once systems are installed.

In this context, reality capture serves as a verification tool. Scans performed at specific milestones, such as after structural completion or before mechanical system installation, provide data that confirms whether dimensional criteria have been met. If conditions fall outside acceptable limits, teams can adjust before additional trades mobilize. The proactive use of scanning helps reduce unplanned work and accelerates the pace of modern builds.

Remote inspections for reduced risk

Scanning accelerates field verification by reducing the need for repeated manual measurements. When construction zones become congested with installed systems, accessing specific points for spot checks can be hazardous and slow. Laser scanning captures data remotely, allowing technicians to remain at safe distances.

Captured data also allows for virtual inspections by off-site team members, which reduces travel time and helps field and office teams stay in agreement without repeated in-person sessions. Less time spent on manual measurement tasks increases overall on-site productivity.

Scan data supports systemwide improvement

While reality capture provides a foundation of accurate spatial data, its value increases when integrated with broader construction practices. For example, linking laser scans to layout tools, quality assurance systems and manufacturing workflows creates a seamless chain of information that reinforces accuracy throughout the project lifecycle. Prefabrication and modular construction also benefit from scan-based validation. By verifying site conditions prior to building, teams reduce assumptions and align offsite work with what is physically present. Pre-planning helps ensure that modular assemblies integrate smoothly with field-built elements. In addition, scanning strengthens quality assurance and acceptance processes by documenting conditions to a level of detail that can be reviewed and archived. This documentation can be part of contractual quality management processes and help resolve disputes about dimensions or installation errors.

Digital documentation that lasts

Accurate as-built documentation is valuable beyond construction. Facilities that support digital services are frequently upgraded, reconfigured or expanded. A detailed 3D record of installed systems provides owners and operators with a reference for future modifications, maintenance planning and lifecycle management. When scan data is integrated with BIM, it creates a baseline that can be updated over time. This evolving digital representation leads to more efficient planning for changes, reducing downtime and risk associated with future work in highly engineered environments.

Demand drivers and data center expansion

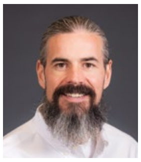
The scale of data center construction underscores the pressures facing design and delivery teams. In addition to the financial growth of the market, demand for capacity continues to rise. Analysts estimate that global demand for data center capacity could increase nearly threefold by 2030 (McKinsey & Company), driven by hyperscale cloud and artificial intelligence workloads. This growth translates into faster delivery timelines, made possible by repeatable standard building blocks and parallel construction rather than sequential. Industry observers note that project durations are tightening, with some large data center builds planned for completion in 12 to 14 months from groundbreaking. Rapid completion requires both verified field information and efficient collaboration among stakeholders, functions that reality capture technologies support directly.

As facilities continue to expand in size, manual progress tracking becomes impossible. The real power of 3D scan data is that it turns a massive, constantly changing jobsite into a continuously updated digital environment. One striking example of this new scale is Meta's Louisiana data center project. Designed to span 2250 acres with 4 million square feet of facilities and multi-gigawatt compute capacity, it highlights just how critical digital measurement has become.

Scanning as the standard

Data center construction presents a convergence of tight tolerances, dense infrastructure and compressed schedules that are distinct from many other building types. In this context, 3D laser scanning has become an essential tool for providing reliable, high-resolution field measurements that represent site conditions. Integrating that data into digital models helps teams match field work with design intent and allows efficient prefabrication, coordination among trades and field verification.

As demand for data center capacity continues to grow and project timelines remain constrained, reality capture activities support construction that meets both performance and schedule requirements. The industry's shift toward connected digital workflows reflects the need for reliable information at every stage of delivery, and laser scanning provides a scalable method in technically complex environments. ▪



Duane Gleason started in the industry with a shovel in his hand, working on several large and complex plumbing and mechanical projects in Washington, D.C. His affinity for construction technology emerged when he became involved with CAD while creating sleeve and layout drawings for a mixed-use project at Georgetown University of more than one million square feet. Drafting soon turned into a role overseeing coordination efforts, which evolved into a position supporting prefabrication work. He joined the technology segment with the belief that there is a genuine opportunity to evolve the construction industry. Years of practical experience, combined with BIM services work and product management, have given him the foundation to drive Trimble's Connected Construction portfolio of products.

Dubrovnik and the Long Game: EAASI’s Seventh Summit Takes Stock of a Changing Industry

From a founding idea shaped by a uniquely European challenge to a seventh Partner Summit that tackled GPS jamming, decarbonization, and the future of professional skills: the European Association of Aerial Surveying Industries is earning its place at the table.

BY ADA **PERELLO**

When EAASI’s founders looked at associations like MAPPS in the United States, they found inspiration rather than a template. Europe is not a single market in any meaningful operational sense for aerial survey operators. It is a mosaic of national aviation authorities, competing procurement traditions, and regulatory frameworks that rarely align across borders. Building a collective voice meant working across dozens of jurisdictions, cultivating influence at the European institutional level while remaining credible to member states that guard their own standards closely. That political complexity was the founding challenge—and it remains the defining context for everything EAASI does.

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Dr Roland Stengele, elected President of EAASI at the 2025 Partner Summit in Dubrovnik.

Within this fragmented European landscape, EAASI’s mission has evolved in response to a set of structural challenges shaping the aerial surveying industry today. Despite remaining the key technology for high-resolution mapping of large, nationwide areas, crewed aerial surveying increasingly finds itself positioned between two rapidly advancing domains: drone-based data capture and satellite remote sensing.

Above: Tomaž Petek, President of EuroGeographics and head of Slovenia's national mapping authority, delivering his keynote at the EAASI Partner Summit in Dubrovnik.

In this crowded landscape, its distinct value is not always fully recognised.

At the same time, the sector faces growing operational and market pressures. Regulatory frameworks for cross-border aviation are becoming more complex, while aerial survey operations often receive limited prioritization within air traffic control systems. Public procurement processes, frequently driven by cost considerations, can further constrain the ability to compete on quality. Alongside these challenges, the industry must also ensure it remains attractive to a new generation of professionals in an increasingly data-driven and competitive labour market.

Against this backdrop, EAASI has defined its mission around four core pillars: promoting the value of aerial survey data to decision-makers; amplifying the industry's voice in political and administrative processes; underpinning quality through certification; and strengthening the sustainability of the sector, in both environmental and economic terms.

This mission has been carried forward by three successive presidents. Simon Musaeus led the association through its founding phase, establishing its structure and initial direction. Florian Romanowski expanded its scope, positioning EAASI as a platform that brings together operators, manufacturers, and software developers across the value chain.

At the Dubrovnik summit, members confirmed the election of Roland Stengele, whose mandate reflects a phase of consolidation and strategic focus. His priorities include sharpening EAASI's profile at the European level, building strategic partnerships, and advancing concrete measures to improve sustainability. At the same time, he emphasises the importance of maintaining alignment across the European aerial surveying community through shared standards, while strengthening links with academia to ensure the sector continues to attract and develop the next generation of professionals.

The seventh summit—and why that number matters

The Partner Summit in Dubrovnik was, by any reasonable measure, the most successful in the association's history—in both attendance and the depth of its debates. It was also the seventh. The 2020 edition, forced online by the pandemic, was a test of resilience rather than a celebration of community. The summits that followed rebuilt momentum year by year. By Dubrovnik, EAASI had developed the convening power to attract not only its own membership but also the researchers, public officials, and technology leaders whose presence signals genuine institutional influence.

Tomaž Petek, President of EuroGeographics and head of Slovenia's national mapping authority, outlined how national mapping agencies are rethinking their roles in a world of persistent monitoring and AI-driven analytics. Fabio Remondino of Fondazione Bruno Kessler explored how artificial intelligence is reshaping aerial mapping workflows, from automated dense image matching to quality control. Croatian officials presented the country's current cartographic programs. It is a sign that the conversations EAASI has been quietly building for years—with mapping authorities, research institutions, and public bodies—are now happening at the right level.

A contested sky: GPS jamming as operational reality

No topic at Dubrovnik illustrated the urgency of EAASI's work more sharply than GPS jamming and spoofing. Geopolitical instability has made large swathes of European airspace electromagnetically contested, and for many operators this is now a routine hazard rather than an exceptional risk. One finding from the panel jangled warning bells: the assumption that flying higher reduces jamming exposure is wrong. At survey altitudes, an aircraft's line of sight to jammers can extend 150 to 200 kilometres beyond the project area, multiplying interference sources and translating directly into degraded flight lines, data gaps, and compromised geometric quality.

Left: Audience Delegates at the EAASI Partner Summit in Dubrovnik, where a record attendance reflected the association's growing reach across Europe's aerial survey community. Below: Networking industry professionals gather during a break at EAASI's seventh Partner Summit—conversations that continued well beyond the conference room.

Mitigation, the panel argued, requires a layered approach—multi-frequency receivers, controlled reception pattern antennas for specific scenarios, cryptographic signal authentication, and algorithmic spoofing detectors—rather than any single technical fix. Crucially, the challenge has migrated from avionics into data workflows: lidar trajectories are acutely sensitive to GNSS/IMU degradation, and processing teams increasingly rely on ground control, alternative correction services, and manufacturer-side trajectory recovery to salvage affected datasets. GNSS resilience is now as much a data management discipline as an avionics one.

Decarbonization: Incremental steps, strategic framing

The summit's sustainability panel, moderated by Erik Admiraal, treated decarbonization as a set of concrete operational decisions rather than a communications exercise. Operators described trials of sustainable aviation fuels, mission planning optimizations designed to reduce sortie counts, and early exploration of hybrid-electric platforms for the light twin and turboprop classes that dominate the survey fleet—a pragmatic roadmap of efficiency gains now, with longer-term technology transitions in view.

The panel's framing carried a strategic message for public-sector clients: aerial survey is not a climate liability but an environmental asset. High-resolution airborne data underpins the monitoring, verification, and reporting infrastructure that responsible land and environmental management depends on—from habitat mapping and flood-risk assessment to infrastructure

Dr. Fabio Remondino, Head of the 3D Optical Metrology (3DOM) research unit at the Bruno Kessler Foundation (FBK), exploring the role of artificial intelligence in reshaping aerial mapping workflows.

condition surveys and coastal change monitoring. The aircraft that must reduce its own emissions is simultaneously indispensable to understanding the environments it flies over.

Building the next generation—and the next conversation

Running through the summit's program was a concern that the industry's most immediate sustainability challenge may not be environmental but demographic. EAASI's university and student engagement strand reflects growing anxiety about an ageing workforce and a shrinking pipeline into specialist photogrammetry and airborne sensor roles. Progress on cross-border standardization, meanwhile, remains slow—a regulatory landscape of national mandates and legacy specifications does not yield quickly to dialog. The work here is still largely at the level of raising awareness, though the relationships being built are a necessary precondition for anything more concrete.

Dubrovnik confirmed that EAASI has become what its founders wished: a voice for Europe's aerial survey industry, calibrated to its own complexity. The seventh summit was not a milestone in the way that firsts tend to be; it was something more quietly significant—evidence that the association has the depth and the relationships to tackle problems no single operator or national body could address alone. In a continent of many authorities and competing frameworks, that is no small achievement.

Ada Perello is Communications Manager of EAASI. She has a background in marketing, media and communications and is based in Madrid, Spain. She holds a master's degree in communication and media studies from the University of Valencia and an MBA from the CECO Centre of Studies for Economy and Trade. Her experience includes positions at the Spanish embassy in Tokyo, Japan, the FAO in Rome, Italy and the International Maritime Organization in London, England.

USIBDMATTERS

JOHN M. RUSSO

Accuracy Isn't A Setting

Applying lidar data with intent, validation, and judgment: Why the Level of Accuracy (LOA) framework and practitioner's guide are changing how accuracy is applied in reality capture

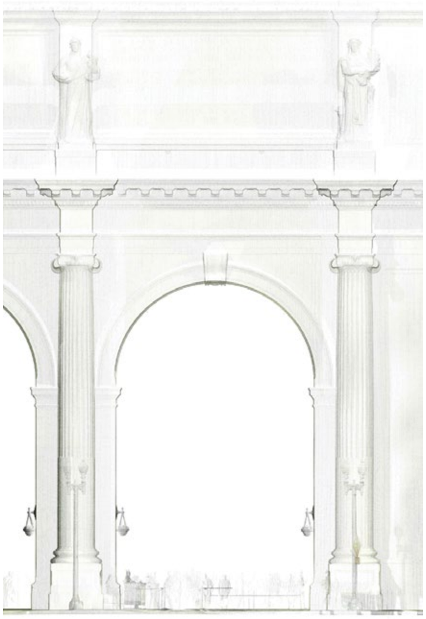
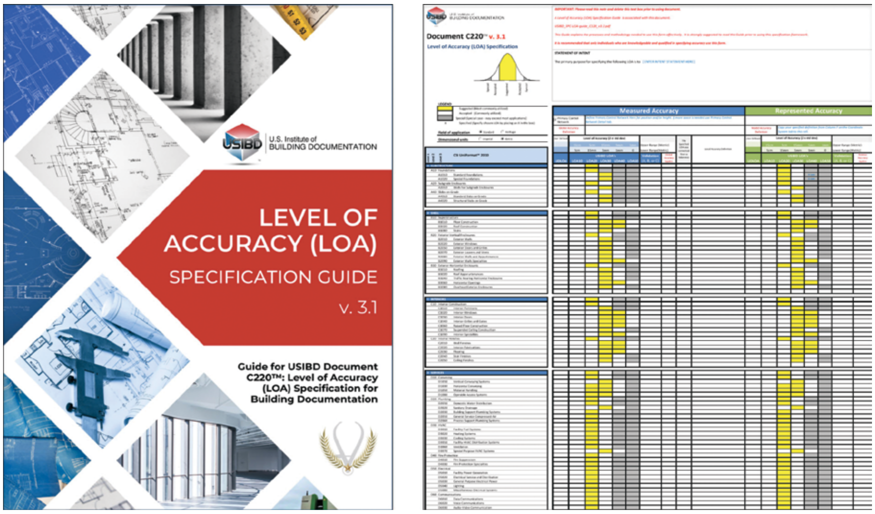


Figure 1: Partial facade scan of Union Station, Washington, DC.

The scan looked perfect (**Figure 1**). The point cloud was dense. Coverage appeared complete. Walls were crisp, geometry looked clean, and nothing raised concern during initial review. From a visual standpoint, the scan checked every box practitioners have come to associate with good data.

Weeks later, problems surfaced. Dimensions did not reconcile. Elements that appeared aligned began to drift when referenced across larger extents. Modeling decisions became uncertain. Confidence eroded, not because the data was obviously flawed, but because its accuracy had never been clearly defined or validated against a known standard.



USIBD U.S. Institute of BUILDING DOCUMENTATION

LEVEL OF ACCURACY (LOA)

SPECIFICATION GUIDE

v. 3.1

Guide for USIBD Document C220™: Level of Accuracy (LOA) Specification for Building Documentation

Figure 2: USIBD Level of Accuracy (LOA) Specification Guide v3.1.

This scenario is more common than most are willing to admit.

In response to this persistent challenge, the U.S. Institute of Building Documentation (USIBD) developed the *Level of Accuracy (LOA) Specification Guide v3.1*[1] (**Figure 2**). The LOA provides a framework for defining how accurate information about existing conditions needs to be relative to its intended use. It replaces vague language with measurable expectations and gives project teams a shared understanding of what can be relied upon.

The LOA does not prescribe how data is captured. It defines the outcome that must be achieved.

Yet, as widely adopted as the LOA has become, many practitioners still face a practical challenge. How is the LOA applied in real-world lidar workflows where constraints, judgment, and interpretation shape the final result?

That gap between specification and practice is what the *LOA Practitioner's Guide* is designed to address.

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[1] Russo, J.M., 2025. USIBD: a new chapter for 2025, *LIDAR Magazine*, 15(1): 40-42, winter 2025.

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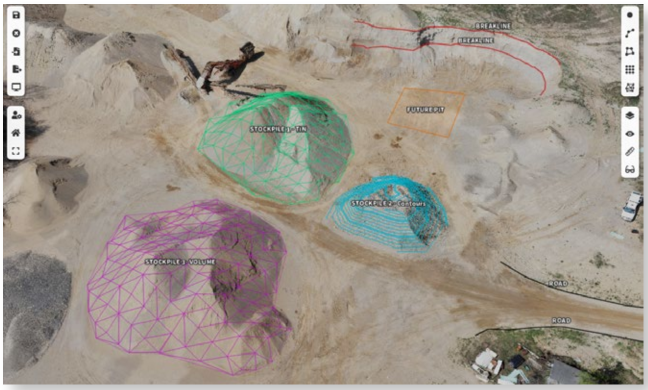

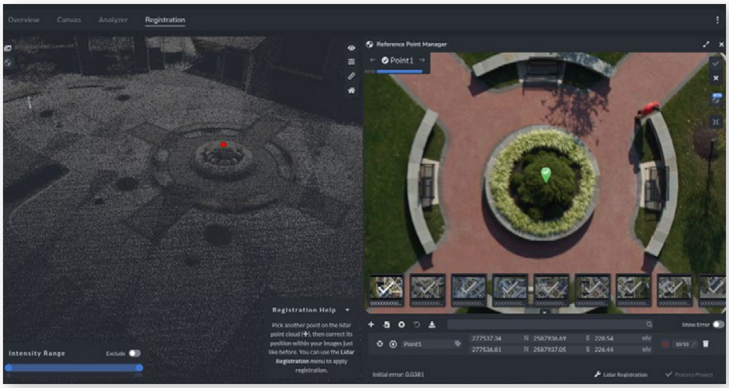

Registration Help

Pick another point on the lidar point cloud (+), then correct its position within your images just like before. You can use the **Lidar Registration** menu to apply registration.

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Initial error: 0.0381

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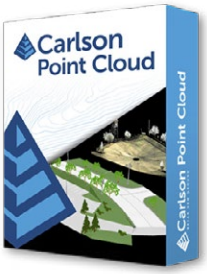

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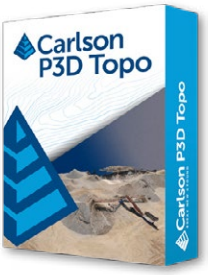

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Carlson
BREAK NEW GROUND

The hidden risk in lidar workflows

Lidar has transformed how existing conditions are captured. Large and complex environments can now be documented quickly with remarkable detail. The resulting datasets appear authoritative, and in many cases, they are. But appearance can be misleading.

Terms such as “accurate”, “high resolution”, and “survey-grade” are often used without clear definition. One stakeholder may interpret “accurate” as suitable for fabrication, while another may understand it as sufficient for planning. Without a shared framework, both interpretations can exist at the same time.

Lidar workflows amplify this issue because the data looks convincing. Dense point clouds create visual confidence even when underlying geometry may be misaligned or weakly constrained.

The risk does not come from the data itself. It comes from how the data is interpreted and relied upon.

The LOA Specification addresses this by defining accuracy in measurable terms tied to intended use. It creates clarity where ambiguity has traditionally existed. However, understanding the specification alone is not enough. Applying it consistently requires a deeper level of interpretation and discipline.

Why precision misleads practitioners

One of the most common misunderstandings in lidar workflows is the confusion between precision, accuracy, and correctness (**Figure 3**).

Precision refers to consistency. Lidar systems generate dense measurements that are highly repeatable. This creates datasets that appear stable and reliable.

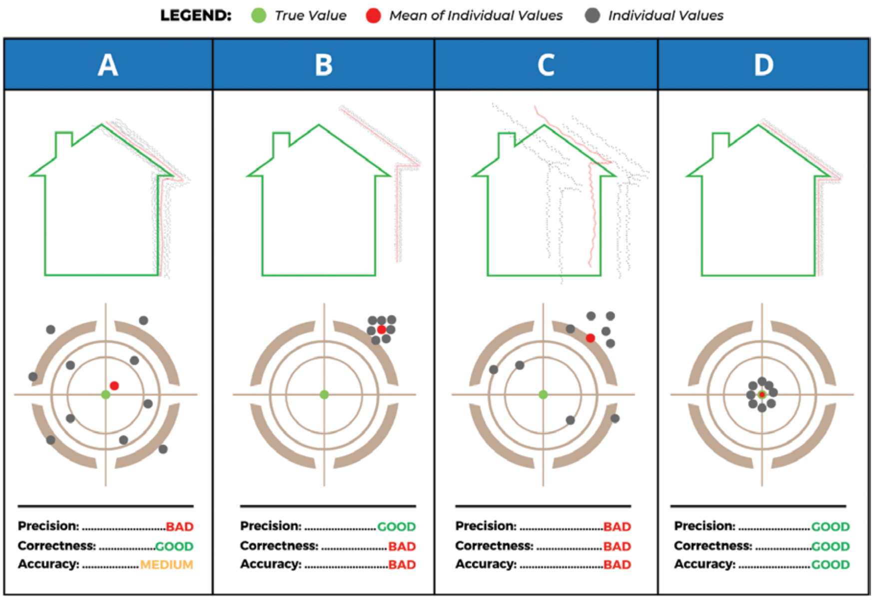

Figure 3: Precision, accuracy, correctness.

Accuracy refers to how close those measurements are to real-world conditions. A dataset can be precise yet consistently offset due to registration error, weak control, or accumulated drift.

Correctness in the context of measured accuracy describes how well a result represents the true value. It evaluates the validity of the outcome, not the method used to obtain it. A measurement may be close to the true value, even coincidentally, yet still be unsuitable for the required LOA if the method cannot reliably achieve the required level of accuracy.

This distinction matters. A long corridor captured as a linear sequence of scans may appear seamless. Each scan aligns with the next, and the geometry looks correct. However, small registration adjustments accumulate with each connection. Over distance, these adjustments can result in measurable drift. The dataset looks right, but it has never been proven to be accurate.

Precision creates confidence.
Validation creates trust.

The LOA helps resolve this confusion by anchoring accuracy to intended use and requiring that it be validated accordingly.

Intent defines process

Accuracy is not a default condition. It is a decision that begins with intent. What will the data be used for? Who will rely on it, and at what stage will they rely on it?

Too often, lidar data is captured for one purpose and later used for another. Data collected for visualization may be assumed to support design. Data captured for planning may be used for coordination. In these cases, the original intent is lost, and new expectations are followed without verification.

The data does not change, but the risk does.

Within the LOA framework, intent forms the basis for defining accuracy. It informs the selection of methods, the level of effort, and the validation approach. Without clearly defined intent, accuracy becomes subjective and difficult to defend.

When intent is defined early and preserved throughout the project, the resulting information is far more likely to be reliable and fit for purpose.

Field execution still matters, but it is not the whole story

Experienced practitioners understand the importance of sound field practices. Traversing, loop closure, control, and geometric strength remain fundamental regardless of technology. Lidar does not replace these principles. It depends on them.

Strong field execution, however, does not guarantee accuracy. It creates the conditions under which accuracy can be achieved.

A well-structured scan network can still fall short if the required level of accuracy was never defined. Conversely, data collected under constraints may still be suitable if its limitations are understood and aligned with its intended use.

> *The field is where accuracy is built.*
> *Validation is where it is proven.*

Validation: The most misunderstood step in lidar projects

Many accuracy issues do not originate in the field. They emerge during validation.

Validation is often treated as a final check. In practice, it should be defined at the beginning of the project as part of the overall accuracy strategy. Defining accuracy without defining how it will be validated introduces significant risk.

A common failure occurs when validation methods do not align with the level of accuracy being evaluated. For example, measuring across a room from one wall to another may seem like a reasonable check. In reality, this approach compounds deviations from multiple surfaces, each of which may fall within acceptable tolerance individually.

The result can suggest that the dataset is inaccurate, even when it meets the required criteria.

This type of mismatch can lead to unnecessary rework, disputes, and loss of confidence.

> *Most accuracy disputes are not caused by bad data.*
> *They are caused by bad validation.*

Validation must be intentional and appropriate to the required outcome. Comparing overlapping datasets can reveal internal consistency. Independent measurements can confirm alignment with real-world conditions. Each method has value, but only when applied correctly.

Figures 4 and **5** illustrate one example of validation through comparison of independent overlapping laser scan datasets. Two separately captured datasets are intentionally overlapped and compared against one another to evaluate consistency and reveal potential registration deviation. This type of comparison can help identify drift, alignment weakness, or accumulated error that may not be visually apparent within a single dataset alone.

One of the most practical contributions of the *LOA Practitioner's Guide* is how it connects validation concepts such as overlapping dataset comparison, independent verification, and fit-for-purpose evaluation to real-world workflows. It helps practitioners understand not only what methods exist, but when and why each should be used.

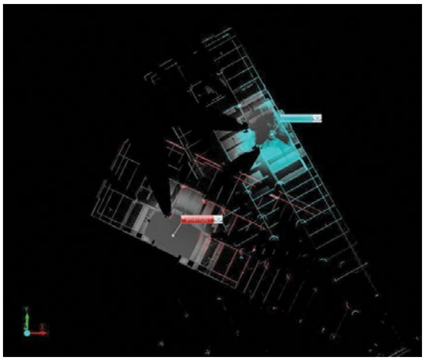

Figure 4: Two independent laser scan datasets.

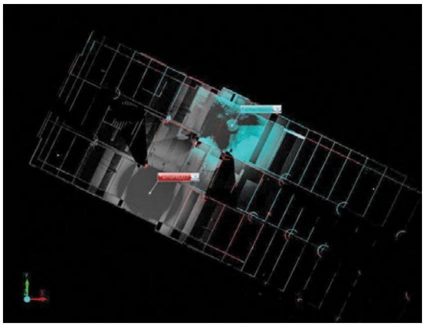

Figure 5: Overlapping laser scan data sets.

When validation is clearly defined and aligned with intent, it reinforces confidence. When it is improvised, it reintroduces ambiguity.

Measured and represented accuracy

Lidar workflows often extend into modeling and documentation. This introduces a critical distinction between measured accuracy and represented accuracy.

Measured accuracy describes how closely the captured data reflects real-world conditions. Represented accuracy describes how closely the model reflects the measured data. A model cannot be more accurate than the data it is based on.

This distinction is often overlooked. There is a tendency to assume that modeling can refine or improve accuracy. Modeling translates accuracy — it does not enhance it.

Understanding this relationship is essential for ensuring that downstream users interpret the information correctly.

Controlled abstraction: Where judgment defines quality

One of the most important aspects of working with lidar data is controlled abstraction. Not everything that is measured should be modeled exactly as it exists. Real-world conditions are inherently irregular. Walls are rarely perfectly flat. Floors vary subtly. Structural elements deviate in ways that may not matter for most applications. Modeling every variation introduces unnecessary complexity and reduces usability.

Controlled abstraction is the process of deciding what to simplify, what to preserve, and how to represent measured conditions in a way that supports the intended use. This is not about reducing accuracy. It is about applying it intelligently.

In practice, this becomes especially important for design workflows. Designers often prefer walls to be modeled orthogonally so they can dimension spaces clearly. When opposing walls are modeled as slightly non-parallel, reflecting true field conditions, it can complicate layout and coordination.

This is where abstraction becomes a deliberate decision. Rather than modeling walls exactly as measured, practitioners may apply best-fit methodologies to represent those walls as orthogonal. The variation is distributed evenly across the length of the wall so that the geometry remains usable while staying within acceptable tolerance.

The LOA provides the boundary for this decision. As long as the represented condition remains within the defined tolerance relative to the measured data, the abstraction is both valid and defensible.

> *Accuracy is not about modeling everything.*
> *It is about modeling what matters correctly.*

Over-modeling introduces noise. Under-modeling introduces risk. Controlled abstraction balances both. It is where technical capability becomes professional expertise.

Accuracy as a risk management tool

Accuracy is often viewed as a technical attribute. In practice, it is a form of risk management. Defining accuracy clearly allows project teams to understand what level of confidence they can place in the information. It reduces reliance on assumptions and aligns expectations across stakeholders. Without this clarity, risk is not eliminated. It is transferred downstream, where it appears as coordination issues, redesign, and disputes.

The goal is not to achieve the highest possible accuracy. It is to achieve the right accuracy for the intended use and ensure that it is understood by everyone involved.

Raising the standard for lidar practice

Lidar technology continues to advance rapidly. Faster capture, improved processing, and automation are expanding what is possible.

But technology alone does not define quality. As the industry becomes more reliant on measured reality, the consequences of misalignment between data and expectation become more significant. Decisions are increasingly based on digital representations of physical environments. The reliability of those decisions depends on how well accuracy is defined, achieved, and validated.

The LOA Specification provides the framework for doing this. It establishes a common language and a structure for aligning expectations. The *LOA Practitioner's Guide* (**Figure 6**) builds on that foundation by bringing the framework into practice. It helps practitioners apply accuracy in real-world conditions where constraints and judgment play a central role. Accuracy is no longer just a technical attribute. It is a professional responsibility.

Accessing the LOA framework and practitioner resources

Practitioners looking to strengthen how they define, apply, and validate accuracy in their work can access the full Level of Accuracy framework through USIBD[2]. A free copy of the LOA Specification is available for download at https://usibd.org/level-of-accuracy/.

For those seeking practical guidance on applying the LOA in real-world workflows, the *LOA Practitioner's Guide* is available for purchase as an electronic download through the USIBD online store[3]. Additional resources, including LOA training and certification, are offered through the USIBD Education Center, providing a structured path for practitioners to build confidence, improve consistency, and apply accuracy

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[2] https://usibd.org/level-of-accuracy/

[3] https://www.bd-pros.com/usibd-loa-practitioners-guide

Figure 6: USIBD *LOA Practitioner's Guide*.

in a way that is both defensible and fit for purpose.

John M. Russo is a recognized authority in building documentation and digital twin implementation, with more than four decades of experience in the architecture, engineering, and construction (AEC) industry. A licensed architect in the State of California, he began his career in 1983, working with architectural firms specializing in healthcare facilities, where he developed a foundational understanding of how buildings are designed, documented, and managed across their lifecycle.

In 1997, Russo founded Architectural Resource Consultants (ARC), establishing a practice dedicated to advancing the accuracy, reliability, and usability of existing conditions data. Under his leadership, ARC has been at the forefront of integrating reality capture technologies, BIM, and spatial data management into practical workflows that reduce uncertainty and support informed decision-making across design, construction, and facility operations.

Russo is the founder of the U.S. Institute of Building Documentation, where he now serves as an Emeritus Board Member. He is the principal author of the Level of Accuracy (LOA) Specification, a foundational industry standard for defining and communicating the accuracy of building documentation. His work continues to influence the evolution of industry standards and best practices, including advisory involvement with the BIMForum LOD Working Group and ongoing efforts to align technical standards with real-world application.

Over the course of his career, Russo has led documentation efforts for some of the most complex and recognizable facilities in the United States, including the Jet Propulsion Laboratory (JPL), Los Angeles Union Station, Union Station in Washington, DC, and the antenna mast of the Empire State Building. His contributions also extend to federal initiatives, including the development of laser scanning quality assurance and quality control guidelines for the U.S. General Services Administration (GSA).

A frequent speaker and published author, Russo continues to advocate for the practical application of standards and the advancement of building documentation as a critical discipline.

LASTRETURN

RON ROTH

Another Wavelength

Ouster recently announced the new REV8 OS product family, billed as the 'World's First Color Lidar'. This might not sound like a significant advancement, as "colorized" lidar data has been available for over twenty years, fusing aerial camera and lidar data collected from the same flight. If you dig deeper, though, true-color lidar stands out as a significant development. Let's look further.

Intensity (monochromatic return signal amplitude data) was available starting in the late 1990s on airborne lidar systems. That allowed users to distinguish between two surfaces at the same distance or elevation, because the different surfaces had different reflectivity at the laser wavelength. An airport runway was therefore distinguishable from the grass around it and the stripes on it, by virtue of their different reflectivity, even though they would all be at a similar elevation.

Later on, sensor manufacturers developed software that could associate the color of a particular pixel in a camera image with a particular lidar data point. The result: colorized lidar data. This became useful in creating more photorealistic lidar data and, as lidar point densities increased, resulted in impressive data sets.

The challenge with colorization techniques lies in a couple of design limitations. First, the imaging sensor collects large images at relatively slow intervals (seconds). Lidar collects a series of individual data points (or a number of parallel lines) at high rates (think MHz). This results in an inherent time mismatch between the collection of lidar points and the associated camera pixels. Think about a stopped vehicle in the camera data, but not in the associated lidar data. Hence, road-textured cars and car-colored roads. Second, clouds, shadows, or nightfall limit the chromatic accuracy of lidar data colorized by camera images.

The first challenge above can be addressed using what might be called a "single pixel imager", where a single color pixel is collected each time the laser fires. However, this still does not solve the second challenge, dealing with lighting variations.

"Color lidar" solves both issues. Although multi-spectral lidar systems have been available for about a decade, these systems tend to use lasers at readily-available wavelengths, such as 532nm (green), 1064nm (infrared) and 1540nm (infrared). Not entirely within human perception, colorization based on current multi-spectral lidar is not generally photorealistic. That said, a lidar system using three wavelengths, all within the visible spectrum, has the potential to deliver accurate color rendering. As an active sensor, the color data derived from the three wavelengths will be consistent, regardless of illumination. This means equally accurate color data, day or night, greatly simplifying the task of classifying data based on color.

Ouster's new multicolor design therefore allows distinction between different surfaces at the same distance and having the same overall reflectivity, so long as there is some difference in at least one color band. A green street sign and a red stop sign would look distinctly different in a true-color lidar, even at the same range and having the same overall reflectivity. In addition, those same road signs will be consistent whether the data was collected in daylight or at night, in direct sunlight or in shade.

So, a true multicolor lidar solves lots of issues, particularly in the areas of alignment and illumination. It also offers a potential boost in maximum-range performance. Maximum range is typically limited by signal-to-noise ratio (SNR) and improves as the square root of the laser output. Combining the return signal of three lidar channels results in a 73 percent increase in maximum range, close to Ouster's claims of doubled maximum range.

Whether used for mapping, vehicle guidance or machine-vision applications, this new technique offers lots of benefits. Perception sensing has made another step forward.

Ron Roth is Associate Editor at LIDAR Magazine. He holds a BS in Mechanical Engineering from Worcester Polytechnic Institute, an MBA from Babson College, and is a former optomechanical design engineer and airborne lidar product manager.


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